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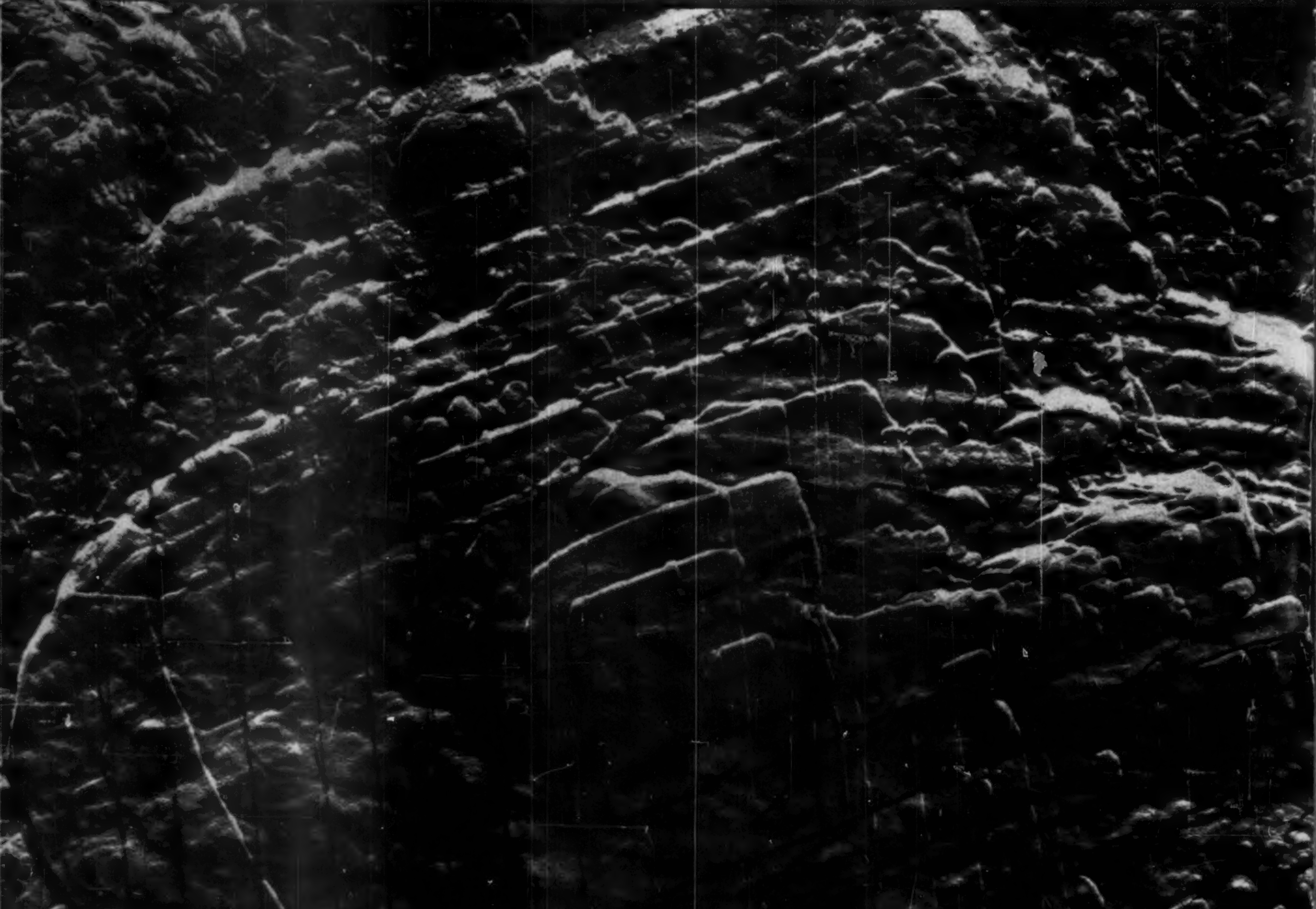

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In This Issue...

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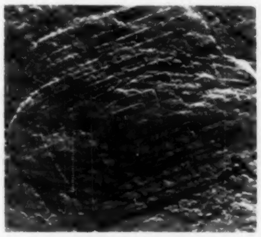
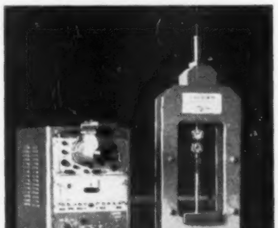


SPIRAL GROWTH PATTERN IN A SINGLE CRYSTAL OF POLY(ETHYLENEOXIDE) GROWN FROM SOLUTION

Crystal grew by a screw dislocation mechanism resulting in spiral ramps having step heights of a few hundred Angstroms. Geometry of the spiral reflects the basic structure of the crystal. Carbon replica preshadowed with chromium. Magnification 20,000×. Twelfth ASTM Photographic Exhibit. Honorable mention, electron micrographs—replicas. A. S. Holik and F. P. Price, General Electric Co.; Schenectady, N. Y.

Nike-Zeus Missile roars aloft from White Sands Missile Range



Model 591A Plastechon Universal Tester

Materials
Research & Standards

Volume 1, Number 11, November, 1961

Reminder: Look Before You Leap

EVERY ONCE IN A WHILE an author comes along with a treatment of a general subject that gives a clear perspective of the basic problems involved and that makes a lot of sense to both the expert and the layman. This is just what W. J. Youden has done in his paper on page 862 of this issue. The subject is experimental design, a topic that is normally discussed from the viewpoint of the statistician but is here discussed from the viewpoint of ASTM technical committees and the problems they encounter in developing and evaluating test methods and procedures.

If the advice given by Dr. Youden in this paper were to be more generally followed, I believe that great savings to industry would result. He advises, for example, that the initiation of a highly organized data-collecting project involving many laboratories be delayed until sufficient work has been done to identify and clear out the basic defects of the procedure. He points out that a vast amount of testing time can be wasted in elaborate interlaboratory test programs on procedures having shortcomings that could have been revealed by modest preliminary tests. He indicates the type of supporting evidence that should be offered with a proposal for a committee to carry on an interlaboratory test. He also suggests certain simple graphical tests for checking the significance of results obtained from several sources.

By and large, Dr. Youden's proposals are reminders—but a nice little package of important reminders—that will be recognized by committees that have had occasion to plan or to participate in interlaboratory studies of test methods. He would especially have us avoid the type of situation that L. H. C. Tippett describes[1] this way: "Until comparatively recently, it was common for an experimenter to complete his work without considering the requirements of statistical analysis, and for him to turn to statistics only when results were in such a mess that he could make little of them. Then he would often find that the statistician also could make little of them." Dr. Youden, in his notably clear and readable style, is specific in urging adequate evaluation of a test procedure prior to the collection of large quantities of multi-source data to be analyzed by statistical methods.

HAROLD F. DODGE
Member Advisory Committee and Past-Chairman,
Committee E-11 on Quality Control of Materials

[1] L. H. C. Tippett, "Technological Applications of Statistics," John Wiley & Sons Inc., New York, N. Y., 1950, p. 159.

Experimental Design and ASTM Committees

By W. J. YOUDEN

This paper considers the subject of experimental design from the viewpoint of ASTM committee members concerned with devising and evaluating test procedures. Simple designs are described that make for an efficient approach to the identification of defects in a test procedure. Suggestions are made regarding the supporting evidence that should be offered by an initiating laboratory before conducting an interlaboratory test. A preliminary type of interlaboratory test is advanced as a means of checking on the claims made in behalf of a test procedure.

THERE ARE numerous textbooks available that present a systematic account of the various types of experimental design and the analysis of variance appropriate for each type of design. Why then should anyone undertake to write on experimental design for ASTM committees? The answer appears to lie in the fact that statistical texts organize the material on experimental design from the viewpoint of statistics. There is a need for expositions that emphasize the objectives and problems that confront ASTM committee members. This paper discusses certain problems that arise in the progress of a test procedure from its inception to the status of a standard procedure. It offers an approach to those recurring statistical problems of general concern regardless of the particular material involved.

The Inception of a Test Procedure

A new test procedure, or a modification of an old procedure, begins in a laboratory. The research involved in devising a test procedure calls for expert knowledge of the material to which the procedure will be applied. The test procedure must serve a useful purpose. Usually it evaluates some property of the material that must be known within certain limits. Satisfactory estimates of the properties of material are required for the safe and economical use of materials and for the setting of fair values in the exchange of materials. The initiating laboratory should be able to supply certain information before requesting that a group of laboratories participate in a round-robin evaluation. There are defects in a test procedure that are best ascertained by work *within* one laboratory, and only confusion results if the detection of these defects is attempted using the less sensitive comparisons associated with interlaboratory tests.

Many test procedures are used to predict the performance in use of the material undergoing test. The laboratory or agency proposing a test must bear in mind that the test will be used for prediction purposes. Devising an adequate test procedure is often a major research problem. A round robin reveals the agreement or lack of agreement among the test results obtained by different laboratories. Agreement among the laboratories does not establish that the test procedure provides a satisfactory measure of the performance of the material. Agreement among laboratories is a necessary even though not a sufficient criterion of a good test procedure. This paper takes up the question of attaining agreement among laboratories.

A test is made on a sample or specimen. The initiating laboratory should, based on its expert familiarity with the material, undertake to specify what sort of a sample, or samples, composite or otherwise will be needed. Good tests are simply wasted when used on poor samples. A quick and simple test may suffice for a heterogeneous material represented by one or two samples.

We will suppose that the laboratory has a procedure that appears to be satisfactory. What supporting evidence does the committee have a right to expect from the initiating laboratory? It is useless to exhibit an array of corresponding results obtained on aliquots of a sample or by one operator doing his very best to "hold everything constant." What is needed is positive evidence that the results check acceptably when deliberate variations are made in the test conditions. These variations should be of the size likely to be encountered when several laboratories are presumably following the procedure.

As an example, suppose that the samples have to be placed in an environment of specified humidity and temperature for a certain period of time. The initiating laboratory may subject a dozen samples to this conditioning and obtain excellent checks. A dozen samples sent one each to twelve laboratories yield twelve results with considerable scatter. The explanation is simple. Let the required temperature be 80 C, the relative humidity 60 per cent, and the time 1 hr. Suppose the initiating laboratory for its test sets 78 C, 55 per cent humidity and takes them out after 56 min. Of course, the twelve results still check each other nicely—and this proves nothing at all except that the sampling is adequate. Twelve laboratories will set up various temperatures and humidities, all nominally as specified, and be variously inexact about the time, and this may explain the scatter of the results.

The initiating laboratory has the responsibility to vary the test conditions from the nominal specified values to find out what happens. The initiating research often makes use of better equipment and controls than are available routinely. The initiating laboratory should be able to set 80 C, or 78 C, or some other nearby value and hold it there. Likewise with the other conditions. If the laboratory finds it necessary to set and hold the relevant conditions within very narrow limits in order to achieve good checks this may seriously limit the usefulness of the pro-

W. J. YOUDEN's academic degrees are in chemical engineering and chemistry. He began to use statistical procedures in 1925 when he was appointed chemist at the Boyce Thompson Institute for Plant Research, Inc. He held this post for 24 years except for the war period when he served as operations analyst with the Air Force. Since 1948 he has been a statistical consultant in the Applied Mathematics Division of the National Bureau of Standards, Washington, D. C. Mr. Youden is the author of more than 100 papers, has written a book (*Statistical Methods for Chemists*), contributed statistical chapters to several other books, and for six years wrote a column "Statistical Design" for *Industrial and Engineering Chemistry*.

NOTE—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author or authors. Address all communications to ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

TABLE I.—EIGHT COMBINATIONS OF TEST CONDITIONS AND DUPLICATE TEST RESULTS ON 2-IN. CUBES OF CEMENT.

	Combination of Test Conditions							
	1	2	3	4	5	6	7	8
Cement	*A*	*A*	*A*	*A*	*a*	*a*	*a*	*a*
Sand	*B*	*B*	*b*	*b*	*B*	*B*	*b*	*b*
Hours in mold	*C*	*c*	*C*	*c*	*C*	*c*	*C*	*c*
Age at test	*D*	*D*	*d*	*d*	*d*	*d*	*D*	*D*
Initial loading	*E*	*e*	*E*	*e*	*e*	*E*	*e*	*E*
Loading rate	*F*	*f*	*f*	*F*	*F*	*f*	*f*	*F*
Operator	*G*	*g*	*g*	*G*	*g*	*G*	*G*	*g*
Duplicate test results, lb	8200	8680	9100	8620	9620	9540	9160	9320
	8100	8220	9240	8980	9480	9600	9100	9360
Average	8150	8450	9170	8800	9550	9570	9130	9340
Difference	100	460	140	360	140	60	60	40

cedure. Therefore, the initiating laboratory should present evidence to demonstrate that the test procedure results will not be altered by departures from specified values of the test conditions that are likely to be encountered when using routine equipment. To use a round-robin test and hope that all will be well is a misuse of the time of other laboratories. Furthermore, the identification of the particular conditions to which the test results are sensitive is impossible using the round-robin data because naturally all the laboratories report that they followed the specified conditions.

Simple Design for Within-Laboratory Study

The committee should be furnished with actual evidence that the test procedure tolerates departures from specified conditions to the extent that may be expected in practice. Simple and sensitive experimental designs are available for the use of a laboratory undertaking to supply this sort of evidence. Clearly, the selection of the conditions to be explored will depend on the material and on the test procedure. This experimental design is so economical and efficient that the laboratory can include conditions which it might ordinarily feel could safely be assumed not to be a source of trouble. The larger the number of conditions explored the more convincing will be the evidence submitted to the committee.

The principle of the experimental design will be developed in a simple example involving a test of just three conditions. Let the specified values for the conditions be A, B, and C and the alternative values, slightly different from the specified values, be a, b, and c. The standard experimental procedure would be to conduct four trials as follows:

Trial	Condition	Observed Result
No. 1	$A\ B\ C$	t
No. 2	$a\ B\ C$	u
No. 3	$A\ b\ C$	v
No. 4	$A\ B\ c$	w

[1] The boldface numbers in parentheses refer to the list of references appended to this paper.

The thought here is that, by varying one condition at a time, the effect of changing a condition will be directly revealed. This is true, but there is a more efficient way to conduct the investigation. The four trials listed below are more efficient in detecting possible effects of changing a condition.

Trial	Condition	Observed Result
No. 1	$A\ B\ C$	t
No. 5	$a\ b\ C$	x
No. 6	$a\ B\ c$	y
No. 7	$A\ b\ c$	z

Notice that *two* conditions have been changed each time from the initial set of conditions A, B, and C. The effect of changing condition A to a is given by taking the difference between the averages of two results.

$$\text{Average result with } A \ldots\ldots \frac{t+z}{2}$$

$$\text{Average result with } a \ldots\ldots \frac{x+y}{2}$$

The two trials with condition A involve B, b, C, and c. This is also true for the two trials at condition a. Thus, the effects associated with B, b, C, and c are present in both averages, although in the combinations BC and bc for A, and bC and Bc for a. The effect of changing from B to b is taken to be independent of the value set for condition C. The justification rests on the expectation that the changes, A to a, B to b, and C to c, have been made quite small, and therefore the changes are not expected to have an appreciable effect on the test result if the test procedure is acceptable for routine work where such small changes in the conditions are likely to be encountered. If the effect on the test result of changing any capital condition to its lower-case counterpart is substantial, the test procedure is in trouble anyway. If we were trying to establish how a test result changes when some test condition, say temperature, is varied over a very large range, then the interdependence with other conditions would be very important and the proposed design would not be suitable.

The fact is that a good test procedure must not be too sensitive to inadvertent small departures from the specified test conditions. Presumably, there will be small consequences of such departures, consequences not much larger than the experimental error and therefore difficult to detect. The use of the averages, instead of the difference between single tests, gives the investigator a better chance to pick up the effects of departures from the specified conditions. Furthermore, it is altogether reasonable to use as a means of estimating the "error" of the test procedure the variation among the four results t, x, y, and z. Not only is it reasonable but more realistic, because surely the performance of the test procedure is given by results of setting up the conditions several times and not from several specimens all exposed to exactly the same conditioning, whatever it happened to be.

Indeed, two or more specimens should be included in each of the four trials and the error within trials (pooled for all trials) compared with that found *between* trials. The committee can, as a minimum, expect to be furnished the between-trial figure for the error, because the results from different laboratories will not be any better than this error and more than likely will be worse.

Illustrative Study of a Test Procedure

Twenty-five years ago Yates (**3**)[1] proposed such "weighing designs" but considered them of merely academic interest because the agricultural investigations that he was familiar with generally involved large effects on the crop yields. The following example using actual data is based on the design he proposed for seven experimental factors or conditions (**8**). This investigation concerned the study of seven conditions that might influence the compressive strength of 2-in. cubes of portland-cement mortar. The conditions were: choice of cements, choice of sand, choice of hours in mold, choice of age at test, choice of initial loading versus no initial loading, choice of fast or slow loading rate, and choice of operators. These seven conditions were assigned values and identifying letters as follows:

Cement	A or a
Sand	B or b
Hours in mold (16 or 24)	C or c
Age at test (65 or 72 hr)	D or d
Initial loading (yes or no)	E or e
Loading rate (fast or slow)	F or f
Operator (Joe or Jack)	G or g

Eight combinations of test conditions are shown in Table I together with the breaking strengths of the duplicate specimens tested for each of the eight combinations. This table shows that combinations 2 through 8 all differ from the

standard combination 1 in that four conditions are changed simultaneously. The changes are made in such a way that the four capital-A combinations contain two capital and two lower-case letters for each of the other six letters. The four lower-case-a combinations also contain two capital and two lower-case combinations of the other six letters. Thus, the effects of these other letters are balanced off against one another when the average of the four combinations containing A is compared with the average of the four combinations containing a. This state of affairs holds no matter which letter is selected to determine the division into two groups.

For example, to compare the strengths of the specimens tested after 65 hr with the specimens tested after 72 hr tabulate the four results for D and the four results for d.

	D (65 hr)	d (72 hr)
	8 150	9 170
	8 450	8 800
	9 130	9 550
	9 340	9 570
Total	35 070	37 090
Average	8 768	9 272
Difference	504	

It is not surprising to find that specimens tested after 72 hr are stronger than specimens tested after 65 hr.

The inclusion of variables that would be expected to have little or no effect will provide direct assurance that differences on the order of 500 are meaningful. Thus, the hours in the mold were either 16 or 24.

	C (16 hr)	c (24 hr)
	8 150	8 450
	9 170	8 800
	9 550	9 570
	9 130	9 340
Total	36 000	36 160
Average	9 000	9 040
Difference	40	

In spite of the use of different cements, sands, and testing ages all of which influence the strength, the two averages representing different times in the mold show excellent agreement. The above results and those for the other five factors are shown in Table II.

This example is a severe test of this method of studying a test procedure. The 10 per cent change in age is greatly in excess of any expected departure from the test conditions. Indeed, two cements might gain strength at different rates. This complication would usually not be present if only one cement were used. The two cements and the excessively different ages were used to make sure that the example would have at least two sizable differences among the comparisons. A satisfactory procedure should give only insignificant differences when modest and reasonable variations are permitted in the test conditions.

TABLE II.—COMPARISON OF RESULTS OBTAINED WITH CHANGED TEST CONDITIONS. BREAKING STRENGTHS, LB.

Condition Changed	Average for Capital Letters	Average for Lower-Case Letters	Difference Between Averages
Cement	8642	9398	756
Sand	8930	9110	180
Hours in mold	9000	9040	40
Age at test	8768	9272	504
Initial loading	9058	8982	76
Loading rate	8960	9080	120
Operator	8912	9128	216

The problem confronting the investigator is the evaluation of the differences listed in the last column of Table II. The differences between the duplicate specimens (Table I) do provide a basis for judgment for all the conditions except cement and sand. The reason for these two exceptions is that the duplicate test specimens always came from the same batch. Comparisons between hours in the mold, ages at test, initial and no initial loading, between loading rates, and between operators use specimens from the same batch. On the other hand, cements (or sands) cannot be compared without making different batches. Consequently, the reproducibility of the batches is involved, and this may make the comparison of sands and cements subject to a larger error than the duplicate specimen error.

The examination of an experimental situation to identify the possible sources of error applicable to any particular comparison is an often overlooked step in the examination of experimental results. If the effect of changing sands is to be justly evaluated, then a number of repeat batches with each sand should be made. The difference found between batches made with different sands can only be judged by the difference found between batches made using the same sand. In the case at hand the change in strength due to changing the sand is small, indicating that both the change in sand and the difference between batches had small effects. The large effect of changing the cement can therefore be judged to arise mainly from the change in cement itself rather than the nonreproducibility of batches.

The eight pairs of duplicate specimens provide an estimate, s, of the standard deviation of a result on a single test specimen. This estimate is based on only 8 degrees of freedom. Triplicate specimens would provide 16 degrees of freedom and, in general, 16 or more degrees of freedom are advisable. The differences, 100, 460, . . ., 40 are squared and divided by $2 \times 8 = 16$, that is, twice the number of pairs.

$$s = \sqrt{\Sigma d^2/16} = \sqrt{399{,}200/16} = 158 \text{ lb}$$

The estimated standard deviation of a *difference* between two averages, when each average is based on n results, is $s\sqrt{2/n}$. The averages listed in Table II are based on eight specimens because duplicate cubes were averaged to get the result for each combination. The standard deviation for the last five differences listed in the last column of Table II is $158\sqrt{2/8}$, or 79 lb. The multiple, t, of this standard deviation that is taken to give a difference not likely to be exceeded by chance depends on the level of probability selected by the investigator and also on the number of degrees of freedom available for estimating the standard deviation. At the 1 per cent level, with 8 degrees of freedom for the estimate, the value for t is 3.36. Consequently, differences of the order of 3.36×79, or about 265 lb, suggest that changing the condition did have an effect. Changing the mold time, operators, the initial loading, and the loading rate all produced smaller differences. With more specimens and firmer averages these differences might be established as something other than fortuitous. The age at test is clearly important at least for this early age. Assuming a linear increase in strength over the interval between the two ages of test (65 and 72 hr), then the 504-lb increase in 7 hr suggests that 1 hr would make a difference of about 70 lb in strength. Clearly the specific time must be adhered to.

There are other factors that might have been studied for their effect on the strength of cubes. For instance, during the time "hours in mold" the specimens in molds are stored in a moist cabinet maintained at 73.4 ± 3 F and not less than 90 per cent humidity. Also the mixing must be done in a temperature between 68 and 81.5 F and a humidity of not less than 50 per cent. The temperature of the mixing slab, dry materials, mold, and mixing bowl are also supposed to be between the latter limits, and the temperature of the mixing water is specified the same as that of the moist cabinet. After the specimens are removed from the molds, they are stored under water, also maintained at 73.4 ±3 F. It is specified that

the water in the storage tank should be kept "clean by frequent changing." Some people feel that too frequent changing leeches the specimens and changes the strength.

Additional Experimental Designs

Designs to study fewer than seven conditions are easily constructed from the schedule shown in Table I. If only five conditions are to be studied, simply note the identifying labels for F and f, and G and g, but make no condition changes for these symbols. The reason for retaining the symbols is that the separation of the eight results into two groups should still be made for each of these letters. The two averages for F and f ought to agree, within the experimental error, because no change in condition was connected with the grouping. The averages for G and g should also agree. This provides a desirable check on the experimental error as revealed by the duplicate (or more) results obtained for each of the eight combinations. Incidentally, interchanging the capital and lower-case letters in Table I gives a quite different selection of eight combinations that possesses all the properties of the set shown in Table I. The conditions retain their assigned letters. Should this second set also be tried, a second set of differences which estimate the effects associated with the changed conditions becomes available. This would provide additional confirmation of any effects indicated by the first eight combinations.

Any number up to eleven conditions, A through K, can be studied by forming twelve combinations using the schedule shown in Table III. This schedule of combinations is from a paper by Plackett and Burman (**2**) that also lists schedules for larger numbers of combinations.

Error of a Test Procedure

The sponsor of a test procedure should make every possible effort to simulate, in his own laboratory, the sources of error, that is, the changes in conditions that will be encountered in different laboratories. In the cement example, different laboratories unavoidably use different batches, and it is, therefore, the reproducibility of the batch that is involved and not merely the agreement shown by duplicate specimens from the same batch. Of course, in studying within one laboratory the effect of changing certain conditons, such as operator or loading rate, there is a real advantage in making comparisons between specimens from the same batch. This was true in the above example. If the effects are negligible when judged in terms of duplicates from the same batch, they will certainly not matter when the error of different batches is also involved, as it is in comparisons between laboratories.

There have been many attempts to define precision and accuracy and the newer terms, repeatability and reproducibility. The case history just discussed shows how the appropriate error term depends upon the actual situation. It is an oversimplification to talk about within laboratory error and between-laboratory error. Men have had little success in framing definitions acceptable to a majority within a committee and even less success in framing definitions acceptable to a majority of ASTM committees. Perhaps we should worry less about defining these terms and concentrate more on devising some set of operations that will readily reveal the vicissitudes to which a test procedure will be exposed. In addition, there is needed a plain statement of the variation exhibited by the test results—say, the standard deviation—when test conditions are purposely varied. At best such an estimate of the performance of the test procedure is likely to be somewhat optimistic, because the initiating laboratory may have neglected to vary certain conditions or varied some of them by too small amounts. It does seem as though it might be relatively easy to devise an acceptable routine for getting data on a proposed test procedure that bears some relation to the real world of testing. No difficulty stands in the way of selecting a statistical technique that will provide a concise representation of the variation among the results. It should be easier for committees to agree on the operations, both laboratory and statistical, than to agree on the meanings of the words, both old and new, that have served as abstract labels.

"Reproducibility is desirable, but it should not be forgotten that it may be achieved just as easily by insensitivity as by an increase in precision."

Example: "All men are two meters tall give or take a meter."

ANON.

The two sands and the two cements in the cement test forced the preparation of four batches, and these were used for the eight combinations. Given a batch for each of the eight combinations the eight batches would give more information on variation arising from batch-to-batch differences. (The cement contrast normally would be used for some test condition.) The laboratory sponsoring the test procedure implies that the test results are not unduly altered by small, unavoidable departures from the specified test conditions. The laboratory should explore such reasonable and inevitable departures. If the sponsoring laboratory believes that it has a satisfactory test procedure, it should be willing to list the eight averages (they may be single results) for the eight combinations and claim no better performance than the standard deviation calculated from these eight results associated with the eight combinations.

If this standard deviation is unacceptably large, then the comparisons listed in Table II should indicate the conditions chiefly responsible. Improved means for setting this condition at its standard value must be devised, or at the very least, the procedure must contain a warning that special, not routine, care is necessary on this condition. All this seems to be a minimum amount of information that should accompany a test procedure under consideration for interlaboratory test. The sponsoring laboratory may have all the fun it wants within its own walls by using nested factorials, components of variance, or anything else that the workers believe will help in the fashioning of a test procedure. At some time the chosen procedure should undergo the sort of mutilation that results from the departures from the specified procedure that occur in other laboratories. The extent of these departures must be based upon expert knowledge of the available equipment and how it is used in routine practice. If the procedure passes this test, it is ready to undergo an interlaboratory test. The interlaboratory test should be a *confirmation* of the claims made for the procedure. The disappointing results so often obtained in round robins are disappointing only in terms of false hopes that were based on unrealistic claims made for the procedure by the sponsoring laboratory.

TABLE III.—SCHEDULE FOR TWELVE COMBINATIONS OF ANY NUMBER UP TO ELEVEN CONDITIONS.

1	2	3	4	5	6	7	8	9	10	11	12
A	A	a	A	A	A	a	a	a	A	a	a
B	b	B	B	B	b	b	b	B	b	b	B
C	C	C	C	c	c	c	C	c	c	C	c
D	D	D	d	d	d	D	d	d	D	d	D
E	E	e	e	e	E	e	e	E	e	E	E
F	f	f	f	F	f	f	F	f	F	F	F
G	g	g	G	g	g	G	g	G	G	G	g
H	h	H	h	h	H	h	H	H	H	h	h
I	I	i	i	I	i	I	I	I	i	i	i
J	j	j	J	j	J	J	J	j	j	j	J
K	k	K	k	K	K	K	k	k	k	K	k

The Interlaboratory Test

A vast amount of testing time has been wasted upon over-elaborate interlaboratory test programs on procedures whose shortcomings would have been revealed by a modest round robin. This section will present briefly a compact program that will quickly assay the claims made for the test procedure. Should the procedure survive this phase, a more searching and necessarily more elaborate interlaboratory program may be undertaken if considered necessary by the committee.

The proposed interlaboratory test requires two samples of about the same nature and value of the property to be tested. These are sent to a dozen or more cooperating laboratories with the request for one test on each sample according to the test procedure. It is recommended that a second pair of samples quite different in value of the property from the first pair also be circulated. Even then each participating laboratory is asked for only four test results.

The very modest assignment per laboratory should make it feasible to increase the number of participating laboratories and improve the basis for judging the performance obtained by different laboratories.

The elimination of duplicates, the restricted number of materials, and the avoidance of the usual falderal of operators, days, etc., introduces an immense simplification. The committee would be very pleased if the reports from a dozen or more laboratories showed excellent agreement with perhaps one or two exceptions. Automatically the results have sampled equipment, days, operators, etc. If the results show acceptable agreement, that is good. If the agreement among the results is not acceptable the method is unsatisfactory and the claims of the sponsoring laboratory have not been confirmed. In other words, the initiating laboratory has not fully explored the possible sources of variation in the place where such effects are most easy to uncover, namely, in its own laboratory.

Much can be learned from a graph prepared using the pairs of results reported for two closely similar samples. Call these samples X and Y. Lay off x and y axes on a graph using a scale so that the lowest and highest values can be plotted for each sample. The same unit of scale must be used for both axes. Now take the pair of results reported by laboratory A for samples X and Y, and using these two results as coordinates plot a point marked A on the graph paper. Do this for each laboratory until a pattern of points appears on the paper, one point for each laboratory.

Plot another point using the average

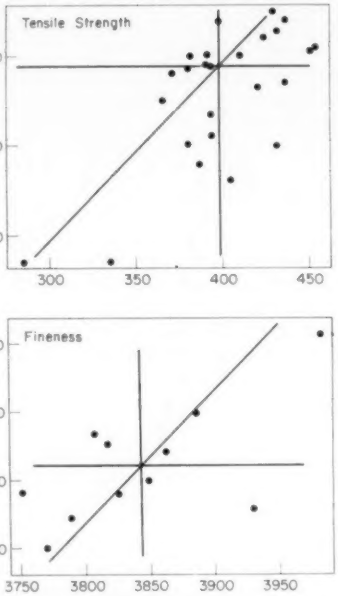


Fig. 1.—Each graph shows two materials tested by several laboratories.

(*Top*) Results for tension tests (psi). (*Bottom*) Results of tests for fineness of cement (sq cm per g). The pair of results reported by a laboratory are used to plot a point. The x axis is used for the result reported on one material, the y axis for the result reported for the other material. In each case one or two laboratories are clearly apart from the main cluster of points.

values for X and Y as coordinates. Draw through this point horizontal and vertical lines dividing the area into four quadrants. If chance errors alone were present in the results, the combinations plus-plus, plus-minus, minus-plus, and minus-minus of random errors would all have the same chance of occurring, and the points would be distributed in a circular pattern around the center with approximately equal numbers of points in each quadrant. The radius of this circular pattern is related to the over-all standard deviation of the test results, sometimes designated as the "reproducibility" of the test.

Usually, however, the points do not form a circle, but a majority of them, and not infrequently nearly all of them, fall in the upper right and lower left quadrants, and more or less close to a line through the center making a 45-deg angle with the X axis. The excess of the plus-plus and minus-minus combinations reflects the presence of some departure from the prescribed conditions for performing the test that carries the same effect over into both results. If this effect is large enough when superimposed upon the small random errors of duplicates, the two results will both be high (or both low) with respect to the grand averages for the two samples.

The points may form a broad oval cluster with only a small excess of points in the plus-plus and minus-minus quadrants. If there are one or two points definitely apart from the cluster and near the 45-deg line, the conclusion may be drawn that these outlying laboratories have failed in some important respect to achieve the specified test conditions. The points are sometimes spread along the 45-deg line in a long narrow oval indicating that nearly all the laboratories were departing from the prescribed conditions. This may come about because the prescribed conditions have not been clearly set forth in the procedure, particularly in the matter of of how closely the standard conditions must be achieved. The procedure may be so vulnerable to even the smallest departures for some of the conditions as to make it impractical for routine use.

The second pair of samples is used for a second graph. Comparison of the two graphs will reveal whether the performance of the procedure changes markedly with the value of the property. If the same laboratory occupies the same extreme position along the 45-deg line on both graphs, this confirms the departure from the specified procedure. A laboratory with points well removed from the clusters but not near the 45-deg line is presumably not even maintaining control of some important conditions. Examples of these two sample graphs are shown in Fig. 1. The reader may make his own interpretation based on the two preceding paragraphs. Detailed accounts of this technique of presenting the results of interlaboratory tests have been published (**4–7**) and applied to a wide variety of tests.

Evaluating the Quality of the Test Procedure

The scatter of the points plotted in the two sample diagrams directs attention to a responsibility all too often shirked by those entrusted with the evaluation of test procedures. The diagrams in Fig. 1 and other diagrams in the cited papers have one or more points clearly apart from the main cluster. What disposition is to be made of the results that are responsible for these outlying points? If the between-laboratory error is calculated using the data from all the laboratories the error is considerably inflated by the retention of the results associated with these points. One answer to the above question is to use all the data to establish the performance of the method on the ground, that, among the laboratories not participating, there may be a few more like the one or two responsible for the outlying points appearing in the diagram. This would appear to put the emphasis on the performance of the laboratories rather than on the inherent quality of the procedure when properly used. The other answer will require directing the attention of all concerned to those laboratories whose

pronounced individuality sets them apart from the overwhelming majority. These laboratories would have the alternatives of justifying their values, or discovering the causes of their troubles and removing them, or of being quietly omitted from the group used to evaluate the procedure. No amount of discussion about accuracy, however prolonged, and no statistical techniques, however complicated, can be substituted for a straightforward facing up to the problem of these outlying laboratories.

The problem of outlying results confronts all those concerned with the improvement of test procedures and all who use these procedures. The statistician can assist the engineers after they have settled in their minds what it is they want. If the decision is made to retain all the data, except clearly bizarre results, the setting of confidence limits may be relatively meaningless. To ask the statistician to make some prediction about a new laboratory is to invite the reply "Is it a good laboratory or a bad one?" And we are right back where we have always been. If the decision is made to set aside some of the results, should it appear necessary, then the statistician can be of considerable assistance in respect to the rules for eliminating results. Confidence limits for points in the main cluster can be set with some assurance that they apply to laboratories of the same competence as those in the main cluster.

It is interesting that in other activities, such as passing a college examination, a standard is set that a large majority of the students can meet successfully. No one is disturbed that some fail for lack of application or equipment. In a very real sense the situation is closely parallel to the performance of the laboratories with a test procedure. Assign a large standard deviation and all the laboratories get in. But an examination that everybody can pass does not do justice to the course nor does it reveal its actual merit. The committees must come to grips with this problem—no one else will.

Acknowledgments:

The author is greatly indebted to Howard T. Arni of the Inorganic Building Materials Section of the National Bureau of Standards who made numerous helpful suggestions. The data in Table I were obtained through the cooperation of Mr. D. N. Evans of the same section who arranged to have the tests made to illustrate the application of this statistical design.

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Tensile Impact Test for Plastics

By R. F. WESTOVER and W. C. WARNER

The work of the Tensile Impact Task Group of ASTM Committee D-20 on Plastics in developing the new tentative tensile impact method (D 1822) is described. A procedure was evolved for measuring the energy to break plastics in tension at high rates of strain. This method has advantages over the conventional Izod and Charpy methods in theoretical simplicity and applicability to sheeting and low-modulus materials. More than 1700 specimens from nine polymer systems were tested. Variables of machine design, specimen geometry, and method of preparation of specimens are discussed. In the final procedure, two specimen geometries are included deliberately to call attention to the danger of generalizing too far from the results of a single set of impact conditions.

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ROBERT F. WESTOVER, member of technical staff, polymer mechanics section, Bell Telephone Laboratories, attended Princeton University, receiving a B.S.E. in mechanical engineering in 1950, and M.S.E. in plastics engineering in 1952. He is presently doing graduate work in engineering mechanics at New York University. He is chairman of the Section on Impact Strength of ASTM Committee D-20 on Plastics.

CONSIDERABLE INTEREST has developed in recent years in tensile impact testing of plastics, because of certain inherent advantages in this type of test as compared to flexural tests (Izod and Charpy). Many investigators feel that the tensile impact test would be a more pure and meaningful test, yielding results that are easier to analyze than those of flexural impact tests. (**1,2,3**).[1] Results from the Izod and Charpy tests are too often clouded by such variables, errors, or parameters as notch sensitivity, specimen preparation errors, compressive stressing, and toss factor. These tests are also limited as to thickness of specimen, determination of effect of orientation and anisotropy, and inability to break low-modulus ductile materials.

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[1] The boldface numbers in parentheses refer to the list of references appended to this paper.

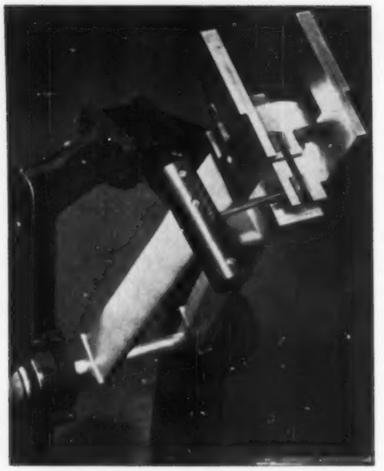


Fig. 1.—Specimen-in-head tensile impact machine.

The Tensile Impact Task Group of ASTM Committee D-20 on Plastics began work in October, 1956, under the chairmanship of J. G. Stranch. The theoretical simplicity of impact in pure tension was compelling. The initial impetus was given by a paper by C. G. Bragaw (**4**), in which a simple and inexpensive adaption of the standard Izod machine was described, making possible the tensile impact testing of plastics. Bragaw replaced the conventional Izod vise with one capable of holding the fixed end of a tensile specimen and secured a metal crosshead to the other end of the specimen. During the swing the pendulum strikes the crosshead, tossing both the crosshead and half of the specimen away. The magnitude of the "toss factor" (the term commonly applied to the correction for the energy required to accelerate half of the specimen and one crosshead) must be determined experimentally (**5,6,7**). The Bragaw machine is referred to hereafter in this paper as a "specimen-in-base" machine.

The other machine considered (Fig. 1) was designed originally by I. L. Hopkins of Bell Telephone Laboratories in 1943 (**8**). Here, the specimen is mounted in the pendulum and attains full kinetic energy at the point of impact, and thus there is no necessity for a toss factor. Other machines have been designed to eliminate the toss factor (**2,9,10**). The Hopkins design is hereafter referred to in this paper as a "specimen-in-head" machine.

Machine Construction

The specimen-in-head and specimen-in-base machines are contrasted schematically in Fig. 2. This figure shows the direction of velocity (approximately 11.3 ft per sec) just prior to striking the tensile specimen at the bottom of the pendulum swing.

In the specimen-in-head machine the crosshead clamp attached to one end of the specimen travels with, and is properly positioned by, the pendulum to which the other end of the specimen is clamped. At the instant of impact, when the pendulum and crosshead have attained full kinetic energy, the crosshead is stopped by the anvils. The pendulum becomes influenced only by the tensile force exerted by the specimen through the pendulum's center of percussion. The bounce or toss of the crosshead in the opposite direction and any energy losses by the crosshead to the anvils are of minor and calculable significance to the pendulum provided that the anvil and machine base are rigid and massive enough to prevent vibrational energy from being transmitted through the frame of the machine

The three specimen-in-head machines (designated A, B, and C) used in these tests were identical in principle. Each had the center of impact coincident with the pendulum's center of percussion, but differed slightly in details and materials of construction.

In the specimen-in-base machine, the crosshead clamp is attached to one end of the specimen, while the other end of the specimen is clamped to the anvil on the machine base. At the instant of impact, the pendulum, which has attained its full kinetic energy, and the crosshead clamp, move together at a velocity somewhat less than the prior pendulum velocity because of momentum conservation. Energy losses in heat and vibration result from the sudden metal-to-metal contact between crosshead and pendulum. Upon fracture of the specimen, the crosshead and attached portion of the specimen are tossed with an energy that is

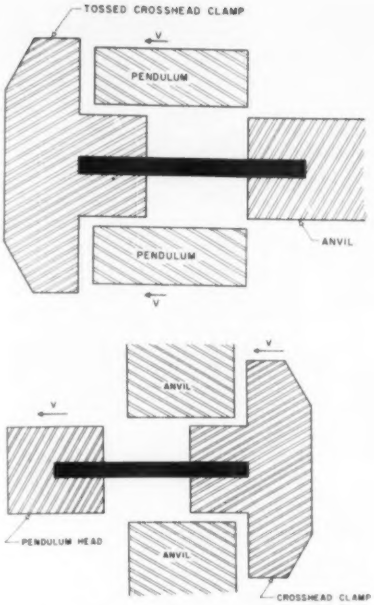


Fig. 2.—Schematic designs of tensile impact machines. (Top) specimen-in-base; (bottom) specimen-in-head.

extracted from the kinetic energy of the pendulum. Thus the mass of the crosshead is a source of momentum and toss errors in the specimen-in-base machine. Calculations must be made to estimate the magnitudes of such errors.

In one attempt to minimize toss errors by reducing the mass of the crosshead, aluminum and magnesium crossheads have been employed. The errors involving mass were reduced, but only at the expense of having plastic strain energy dissipated by nonreversible de-

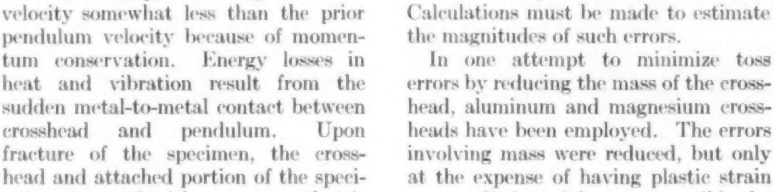


Fig. 3.—Evolution of tensile impact specimen.

formation in the battering of the crosshead by the pendulum.

Specimen-in-base machines (designated 1, 2, and 3) were found to have the center of impact at distances of 0.9, 0.5, and 0.25 in., respectively, from the center of percussion of the pendulum. Machines designated 4 and 5 were specimen-in-base machines in which the center of impact coincided with the center of percussion.

Specimen Geometries

Five specimen geometries were considered. The dimensions of four of these are shown in Fig. 3. The fifth type was of the original circular cross-section described in reference (**4**). This specimen was ruled out for general plastics testing because it could be prepared only by molding procedures.

Figure 3 shows the evolution of the final choice of specimen types S (short) and L (long) from the three earlier test specimen types S, X, and Y. The type X and Y specimens were observed to provide a greater differentiation between materials, while type S specimen provided a greater degree of reproducibility. Such materials as poly(vinyl chloride) or nylon, which owe their usually high energy-absorbing property to their ability to draw, are given a greater region in which to do so in the type X, Y, and L specimens. In the process of drawing, a greater opportunity for specimen-to-specimen variation results.

Geometry of type Y specimen with its larger cross-sectional area was capable of absorbing more energy than could be provided in the available 5 ft-lb capacity machine for some materials tested (see Fig. 4). The smaller radius with its associated higher stress concentration in the type Y specimen caused too many breaks at the radius for some materials. The type X specimen with a restricted section twice the length of type Y specimen presented a slight machining difficulty for some of the low-modulus materials in that the specimen tended to move away from the cutter during machining. Type L specimen evolved from the better features of the type X and Y specimen.

The type S specimen was the forerunner of specimens X and L and therefore is probably the specimen most widely used in the plastics industry. Its geometry was basically unaltered throughout this study.

The presence of two specimen geometries calls deliberate attention to the fact that a reported energy obtained from this or any impact test is not an all-inclusive parameter for the material being tested. Rather, it bears testimony only to the behavior of a material in a specified specimen geometry and under a specific set of testing conditions.

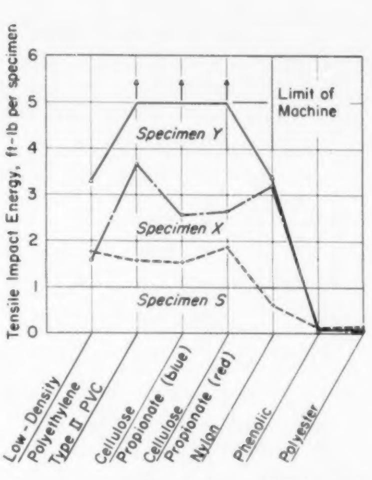


Fig. 4.—Energy to break machined specimens in specimen-in-head machine A.

Regardless of the method of preparing specimens, minor specimen-to-specimen dimensional variations will arise from molding, shrinking, or machining variables. Cooperating laboratories should agree upon standard molds and upon specimen preparation procedures and conditions to minimize these variations. To compensate for the minor differences in the cross-sectional area of the specimens, the energy to break is normalized to units of foot-pounds per square inch of minimum cross-sectional area.

Although the thicknesses of all specimens used in this investigation were nominally $\frac{1}{8}$ in., the thickness need not be so restricted. All present commercially available tensile impact machines can handle specimens of $\frac{1}{8}$ in. or less in thickness. However, only results from specimens of nominally equal thicknesses should be compared unless it has been proved experimentally that the energy (normalized to foot-pounds per square inch of cross-sectional area) is independent of the thickness over the range of thicknesses under consideration.

Specimen Preparation and Conditioning

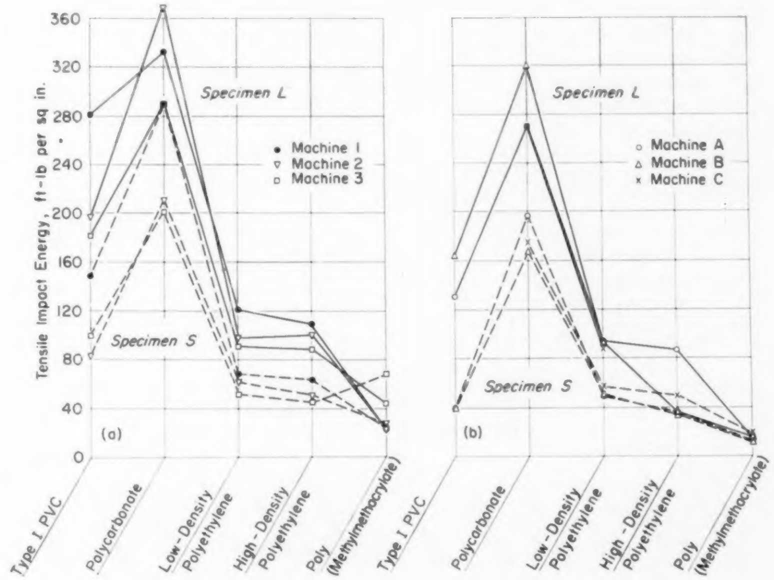
For the study of specimens prepared by machining, geometries of type S and L specimens shown in Fig. 3 were chosen. For the study of specimens prepared by molding, geometries of type S and L specimens shown in Fig. 4 were chosen for the mold cavities. Ten replicates of each material for each method of specimen preparation were tested in each impact machine. One laboratory injection-molded all molded specimens except type I PVC, which was compression-molded at a second laboratory. All type S specimens were machined at a third laboratory, and all type L specimens were machined at a fourth laboratory.

All specimens were conditioned at 73.4 ±1.8 F and 50.0 ±2.0 per cent relative humidity for at least 24 hr prior to testing.

Both ends of each specimen were numbered so that the fracture surfaces could be observed and correlated with the measured impact energy.

Test Results

The results of the study on machined specimens of five molding compounds are presented graphically in Fig. 5(*a*) and (*b*) for specimen-in-base and specimen-in-head machines. Each point



(*a*)—Specimen-in-base machines. (*b*)—Specimen-in-head machines.

Fig. 5.—Tensile impact energy of machined specimens.

plotted is the average of ten replicate tests. Although good agreement was observed among the three specimen-in-head machines, poor agreement was observed among the three specimen-in-base machines. The specimen-in-base machines gave consistently higher energy values than did the specimen-in-head machines. Since the three specimen-in-base machines were all found to be in error in varying amounts with regard to the distance between the centers of impact and centers of percussion of the pendulums, and since the deviation from the specimen-in-head results varied directly with the center-of-impact error, it was felt that properly designed specimen-in-base machines might agree with the specimen-in-head machines. For these reasons the results of this work were not taken conclusively as a comparison between the machine performances.

Two different mechanisms of failure (brittle and ductile) were observed for type I PVC. Hence, two separate groups of impact energies were observed. A brittle fracture with an accompanying low impact energy was experienced by this material with greater incidence for the type S specimen than for the type L, owing to the greater strain rate of type S. Particular attention is drawn to these two types of failure in Fig. 6, which shows the individually plotted points or their limits as well as their averages. Rather than to report an average value of impact energy and the coefficient of variance for such bimodal failures, it would be more meaningful to report two impact energy averages together with the number of specimens failing by each mechanism.

Juillard (**11**) reported three temperature-dependent modes of impact failure (ductile, brittle, and ultra-brittle) for several polymer systems.

Molded specimens of six polymer systems were tested on the same three specimen-in-head machines and on two

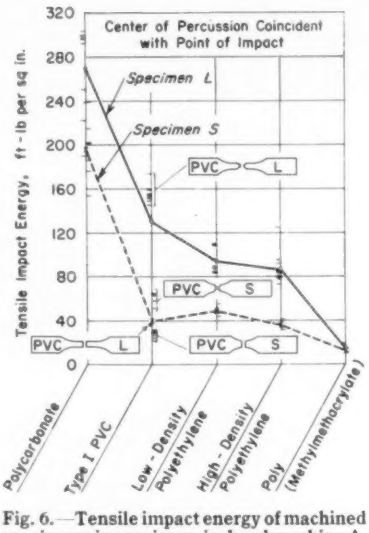


Fig. 6.—Tensile impact energy of machined specimens in specimen-in-head machine A.

new specimen-in-base machines. The center of impact was properly located at the center of percussion in both specimen-in-base machines. Machine 5 had a capacity of only 2 ft-lb and was not able to break all the specimens for all materials. The results of this study are shown in Fig. 7.

Better agreement among specimen-in-head machines was observed for the molded specimens than for the machined specimens. The two improved specimen-in-base machines gave consistently higher impact readings than did the specimen-in-head machines and showed poor agreement.

As in the other investigations, closer agreement between specimen-in-head machines occurred with the type S specimen geometry than with type L. Type L gave considerably better differentiation among materials.

Bounce Correction

Upon contacting the anvil at the bottom of the pendulum's swing, the crosshead of the specimen-in-head machine bounces away with a velocity determined by the elasticity of the contacting surfaces and the energy delivered to the specimen by the crosshead. R. P. Lathrop (**12**) analyzed the mechanics by which it is possible to calculate the energy contributed to the breaking of the specimen by the moving crosshead. The maximum amount of energy contributable by the crosshead to the breaking of the specimen for the case of a single bounce is determined by the crosshead mass and the bounce velocity, v_1, with no specimen in the pendulum. Thus the maximum bounce energy for a single bounce is $\frac{1}{2} mv_1^2$.

The bounce velocity, v_1, of the free crosshead can be determined from high-speed motion pictures or calculated from the trajectory of the crosshead as follows:

$$v_1 = \frac{s}{\sqrt{2h/g}}$$

where:

s = horizontal travel of the center of gravity of the free crosshead before striking the table, ft,

h = vertical distance through which crosshead center of gravity falls from impact position to the table, ft, and

g = local gravitational acceleration (to an accuracy of one part per thousand), ft per sec².

For the usual case of only one strike of the crosshead during a test, the bounce correction for the specimen will lie between zero for specimens that require no energy to break, and the value $\frac{1}{2} mv_1^2$ for specimens that allow no bounce of the crosshead. For bounce corrections at intermediate energies to break, the following equation may be used:

$$e = \frac{m}{2}\left\{v_1^2 - \left[v_1 - \frac{M}{m}\left(V - \sqrt{(V)^2 - \frac{2E}{M}}\right)\right]^2\right\}$$

where:

V = maximum velocity of pendulum, ft per sec,

v_1 = free crosshead velocity immediately after bounce, ft per sec,

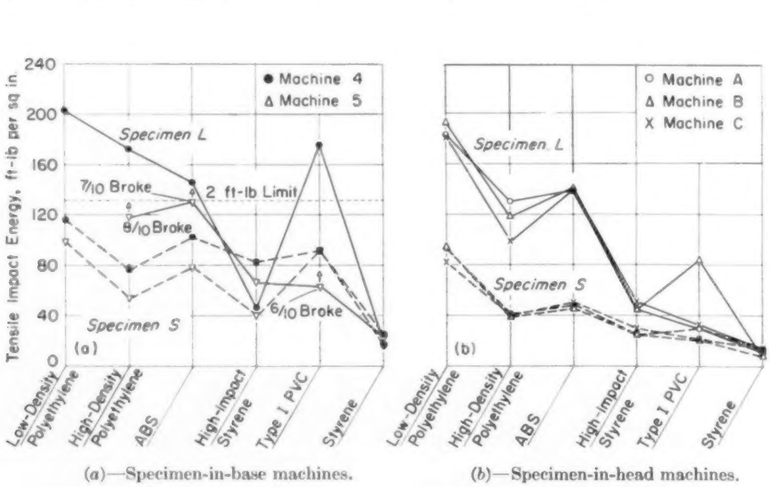
E = energy extracted from pendulum and read on pendulum dial, ft-lb,

M = mass of the pendulum without crosshead, lb-sec² per ft

m = mass of the crosshead, lb-sec² per ft

e = energy contribution of crosshead (bounce correction to be added to pendulum reading) ft-lb.

A typical correction curve for a single



(*a*)—Specimen-in-base machines. (*b*)—Specimen-in-head machines.

Fig. 7.—Tensile impact energy of molded specimens.

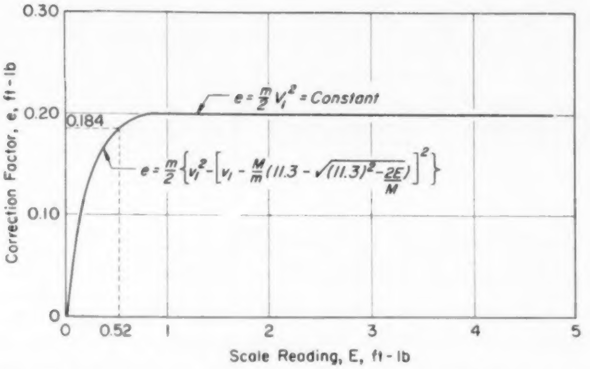


Fig. 8.—Correction factor curve for single crosshead strike for specimen-in-head machine.

crosshead strike is shown in Fig. 8. A separate correction curve is necessary for each machine. All of the data shown in the preceding figures were uncorrected for bounce, (specimen-in-head) or toss (specimen-in-base).

For the special case of multiple strikes of the crosshead, the bounce correction would be indeterminate. Multiple strikes are possible for materials of very low modulus.

Independently, H. S. Loveless (**13**) and R. F. Westover each have verified the accuracy and validity of the above mathematical treatment by measurements obtained from both high speed movies and an analysis of the trajectory of the moving crosshead.

Conclusions

On the basis of this work, the tensile impact task group excluded the specimen-in-base machine from the test method under consideration at present. Two specimen geometries, types S and L, are included in the method. These are subject to agreement between laboratories for selection of the more useful specimen for the particular application.

The tensile impact test method should not be considered a cure-all for impact testing, but rather a new instrument for plastics testing with unique characteristics and great versatility. It should not be expected to displace the Izod or Charpy tests so widely used for material specification and quality control. The Izod and Charpy tests can now be supplemented by this tensile impact test, which is applicable to thin sheets and flexible materials that cannot be tested in impact by other means.

It should be kept in mind that, while ideally the speed of impact testing should be constant throughout the test, the speed of testing for any pendulum impact test is reduced during the specimen deformation. High percentage scale readings and the accompanying greater reduction of testing speed should be avoided by increasing the capacity of the machine with calibrated weights added to the pendulum or with a replaceable pendulum of higher capacity.

The variable of notch sensitivity has been removed from the impact test in the present proposed test method, which uses specimen geometries of types S and L. However, at a later date, other specimen geometries with sharp notches or stress raisers may be considered for studying notch sensitivity as a separate test.

A way of augmenting and extending the usefulness of the tensile impact test suggests itself by the appearance of the test specimens. Tension tests run at different speeds on a conventional tension testing machine could yield comparable results under varying elongation rates. If the 1-in. jaw separation distance is maintained, the energy to fracture obtained by measuring the area under the load-elongation curve can be properly compared with the energy measured by the pendulum impact machine.

Acknowledgment:

The authors wish to express full appreciation and recognition to the many persons and companies who have contributed their time, equipment, and materials to the Tensile Impact Task Group of Section B, Subcommittee I on Mechanical Properties, of ASTM Committee D-20 on Plastics.

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Effects of Variables in Charpy Impact Testing

By NORBERT H. FAHEY

EDITOR'S NOTE.—The Charpy impact test can be used to specify a material property within limits. The causes of wide variation in results, for which the test has long been criticized, have been identified and can be eliminated.

Although the Charpy impact test can be and is an accurate, reproducible research and inspection tool, many persons are not aware of the magnitude of the error that may occur if certain precautions are not observed.

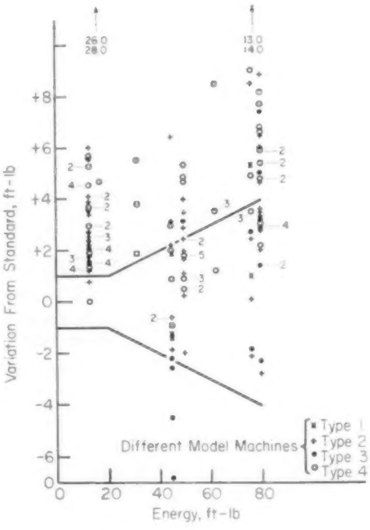
Testing and machine variables causing erroneous energy values in the Charpy test mostly tend to cause erroneously high values, since they retard the swing of the pendulum or otherwise cause excess energy losses. The recorded energy values may be in error by as much as 100 to 200 per cent at low energy levels and 15 to 20 per cent at high energy levels. Several Charpy machines meet all standardized dimensional requirements and yet, because of their design, some of them do not perform satisfactorily. Owing to an excess of stored elastic energies, these machines fail to fracture a specimen which normally would fracture at an energy far below the machine capacity, or if they do break the specimen, the required energy is above that normally expected.

IT HAS BEEN POINTED out by Driscoll (1)[1] that differences in Charpy impact test results are in most cases caused by any one or a combination of the following factors:

1. Condition of Charpy impact machines.
2. Methods of machining and finishing the Charpy specimens.
3. Techniques of cooling and testing specimens.

Driscoll says further that, by exercising proper controls of these variables and by using specially prepared specimens, an average impact value can and should be accurate to within ±1.0 ft-lb for values up to 20.0 ft-lb and ±5.0 per cent for values over 20.0 ft-lb. The difficulty is the problem of convincing the doubtful that the test is an accurate, reproducible research and inspection tool, similar to other mechanical test equipment. This is a serious problem; approximately 150 Charpy machines throughout the country have been checked by Watertown Arsenal for accuracy, and of these, less than 80 machines produced accurate results and were acceptable for Ordnance inspection testing

A Charpy impact machine is designed to conform to certain dimensional requirements set forth in ASTM Methods for Notched Bar Impact Testing of Metallic Materials.[2] No proof or calibration tests are conducted on these machines, unlike hardness and tensile machines. The energy losses due to the design of a particular model machine may be excessive, and although the machine may produce reproducible results, these results may consistently be in error. For example, an impact machine with newly designed anvil supports was recently inspected, and the resultant energy values, although uniform, were found to be approximately 10 per cent high. After modification of the anvil supports, the variance in the machines was found to be less than 1 per cent.



NOTE.—Numbers beside plotted points indicate number of machines giving that energy value.

Fig. 1.—Comparison tests on unmodified Charpy impact machines.

Energy values obtained in the Charpy impact test cannot be correlated directly with service performance but rather are relative values with which one can compare the notch sensitivity of metals. However, unless the machining of the test specimen is within certain specified tolerances, the effects of variations in machine dimensions understood and standardized, and proper testing techniques established, not much reliance can be placed on the resultant values. This paper presents data concerning the known causes of erroneous values and recommends those steps found necessary to obtain accurate reproducible energy values in the different model machines.

PROCEDURE

In order to evaluate properly the reproducibility of the Charpy impact test it is necessary to have a minimum of variance in the test specimen. To ensure this, the material must be uni-

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[1] The boldface numbers in parentheses refer to the list of references appended to this paper.
[2] 1958 Book of ASTM Standards, Part 3, p. 69.

form, necessitating finely controlled procurement, machining, and heat treating procedures. The procedures used have been adequately outlined by Driscoll (2) and will not be repeated here.

Extensive tests were conducted on machines made by four different manufacturers. With the aid of high-speed photography much was learned about the characteristics of each machine by separately varying machine dimensions, machine installation procedures, and testing techniques. When the techniques were sufficiently understood to get each machine to produce energy values within certain allowable limits the specimens were then separated into sets of 15, 5 at each of 3 energy levels, and distributed to the respective Ordnance districts throughout the country for testing.

Figure 1 illustrates the results from 45 machines (four different types) which produced erroneous energy values when first tested, and Fig. 2 shows the results after recommended changes were made in machine procedures or testing techniques or both. These data clearly indicate that accurate energy values can be obtained on most machines if proper machine procedures and testing techniques are observed. Note that in practically all cases the erroneous values are above the allowable limits, which is neither unusual nor unexpected, as most of the faults encountered, such as jamming, looseness of mating parts, worn bearings, etc. cause the pendulum to slow down. This caused an apparent high reading.

The knowledge gained from the program outlined above has been supplemented by other investigations. The impact energy values used in this paper are in most instances average values of at least ten specimens.

The Cause and Cure of Erroneous Results

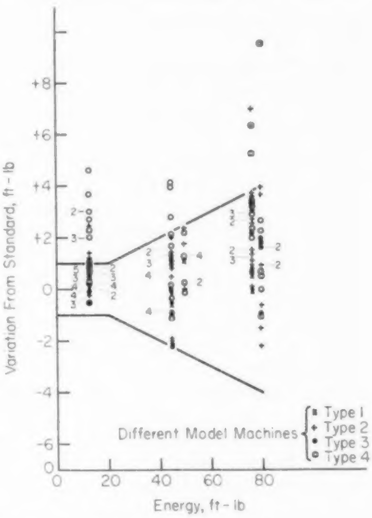
Erroneous energy values were said by Driscoll (1,2) to result from any one or a combination of the following factors: (1) condition of Charpy impact machine, (2) methods of machining and finishing the specimen, and (3) techniques of cooling and testing specimens. Each will be discussed in detail, and in most cases specific energy differences will be included.

Condition of Charpy Impact Machine

For the most part, the Charpy machine is a sturdy, well-built piece of testing equipment, but with the requirements for testing of high-strength material with its resultant comparatively low impact properties, it has become very important to check all critical parts of the machine. The following checks should be made on the machine condition:

Installation

The machine must be level and securely bolted to a concrete foundation. This will ensure a minimum of energy loss due to vibrations through the base of the machine. It has been proved that it is not sufficient simply to grout the machine in cement or to install a steel plate against the base of the machine, since neither sufficiently resists energy absorption. Tests conducted on Charpy machines either grouted in cement or resting against an angle iron have illustrated that specimens requiring 76 ft-lb of energy to fracture will actually indicate energy values of approximately 90 ft-lb. Even if the machine is bolted to a concrete foundation but not securely fastened, energy values of 80 to 85 ft-lb are often encountered. If a machine needs shims for leveling, they should be of steel, as other materials may be too soft and energy could be lost due to absorption through the base if the center of percussion is not accurately positioned at the center of the striking edge.



NOTE.—Numbers beside plotted points indicate number of machines giving that energy value.

Fig. 2.—Comparison tests on modified Charpy impact machines.

Design of Anvils, Supports, Etc.

Charpy tests conducted on brittle specimens at low temperatures have been a particular source of trouble. Such specimens do not leave the machine in the direction of the pendulum swing, as do ductile specimens. A brittle specimen leaves the machine in a sidewise direction, and if the design of the machine is such that there is not sufficient clearance, the broken halves of the specimen will rebound into the pendulum before it passes completely through the anvils. If the momentum of the specimens is sufficient (high-speed pictures have indicated that the broken halves of these brittle specimens leave that machine at speeds of approximately 50 ft per sec), the pendulum will slow down and indicate an erroneously high energy value. This "jamming" is one of the most common problems encountered in the impact testing of high-strength steels and titanium. Marks caused by jamming are evident on the specimens shown in Fig. 3.

Figure 4 illustrates the basic pendulum and two anvil designs. This type of pendulum passes through the anvil assembly, and therefore the broken specimens need not be contained but should be deflected out of the anvil assembly so as not to rebound into the pendulum. This may be done by ensuring a minimum of $\frac{7}{16}$ in. clearance between the ends of the specimen and

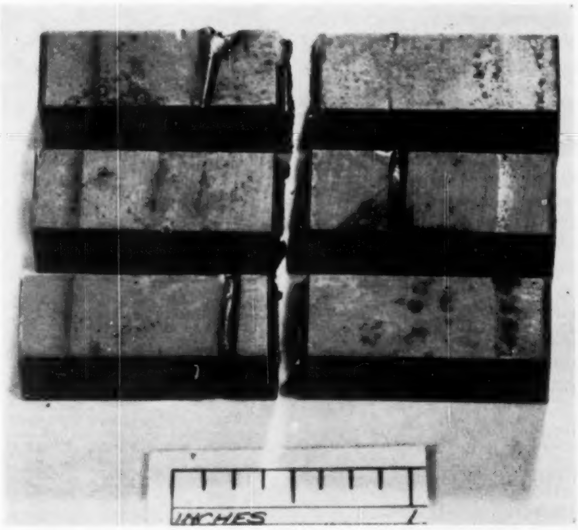


Fig. 3.—Effects on Charpy impact specimens when jamming has occurred.

restricting part, or, if the restricting part is a spacer which is needed to secure the anvil supports, by tapering the spacers as illustrated in the modified anvil.

If, on the other hand, the pendulum is the inverted U-type (Fig. 5), the sides of the pendulum pass outside the anvil assembly and the broken specimen must then be contained within the anvil assembly until the pendulum has passed through the anvils. The anvils cannot be opened at the sides because then the broken specimen will pass out through this opening and contact the overhang of the pendulum. Figure 5 illustrates one of the more common anvil assembly designs and illustrates the modifications recommended to minimize jamming. Besides cutting back the side supports to give a minimum end clearance of $\frac{7}{16}$ in., the installation of the shroud will stop the flying halves of the specimen from striking the underside of the pendulum. This will further minimize jamming. If a low-energy specimen is tested in the unmodified anvil assembly, the recorded energy would be approximately 17 ft-lb, whereas, if the same specimen were tested on the modified machine, the recorded value would be 12.5 ± 1.0 ft-lb. It should be pointed out that in some machines using the U-type pendulum, the anvil assembly is not wide enough to give adequate clearance at the ends of the specimen. If in these cases the side plates of the pendulum are removable, they may be removed, inverted, and widened to give more clearance (see crosshatched sketch of pendulum). Side plates can then be added to the anvil assembly to give the desired clearance.

A recent modification of a machine using the inverted U-type pendulum completely eliminates the side supports. The pendulum has cutouts on each side, and the broken halves of low-energy specimens pass out of the machine through those openings and jamming is minimized.

Conditions and Dimensions of Critical Parts

To obtain accurate reproducible energy values it is essential that the dimensions of certain parts be within certain tolerances.[2] To determine accurately the effects of dimensional changes as well as those due to worn parts, many tests were conducted and the results evaluated.

Anvil Supports.—The most critical dimension on a Charpy impact machine is the radius of the anvil supports (*R*, Fig. 4). The magnitude of the error in resultant energy values when the radius is other than the specified 0.039 ± 0.001 in. is far greater than one would expect. This is shown in tests conducted on a machine whose anvil radii were varied in increments of 0.005 in. Table I shows that a 0.010-in. decrease in anvil radii results in a 13.0 ft-lb spread in energy values at the 76.0 ft-lb range.

[3] Indentations in tested specimen produced by anvil supports and pendulum striking edge.

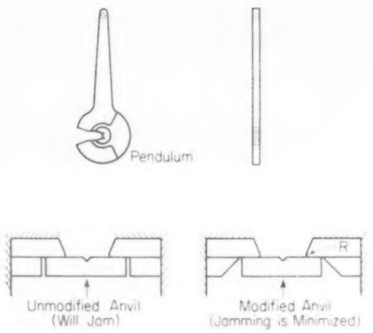


Fig. 4.—Basic pendulum and anvil assembly.

An examination of the fractured specimens indicates an increase in brinelling[3] depth with a decrease in anvil radii. Any excess in brinelling caused by radii sharper than the standard 0.039 ± 0.001 in. results in excess energy being spent in brinelling rather than fracturing the test specimen. This causes erroneously high recorded values for the given test. Table I further indicates that it is safe to assume a 1.0 ft-lb energy loss for each 0.001-in. decrease in anvil radii at the 80.0 ft-lb range.

If the face of the anvil supports is burred or chipped in any way, harmful effects are also noted. Any foreign object or rough edge that will tend to retard the movement of the specimen in the machine or cause the specimen to spin and possibly jam, will also result in an erroneously high energy value. On the other hand, if the face of the anvil support is such that the brinnelling is either less than normal for 0.039-in. radii or such that the brinelling does not extend across the full width of the specimen, the resultant energy will be less than that expected when accurately dimensioned anvils are used. In some cases a combination of normally harmful conditions will have an offsetting effect and the resultant value may be within the allowable limits. Energy may be lost if care is not exercised in assuring that all bolts used to fasten the mating parts are properly secured. Hand tightening is

TABLE I.—EFFECT OF CHANGING ANVIL RADII.

Anvil Radii, in.	Low-energy Specimens, ft-lb	Medium-energy Specimens, ft-lb	High-energy Specimens, ft-lb
0.029......	13.0	47.0	88.7
0.034......	12.8	45.0	80.5
0.039[a].....	12.5	44.5	76.0
0.044......	12.4	42.9	74.0
0.049......	12.3	42.0	72.0

[a] Standard machine.

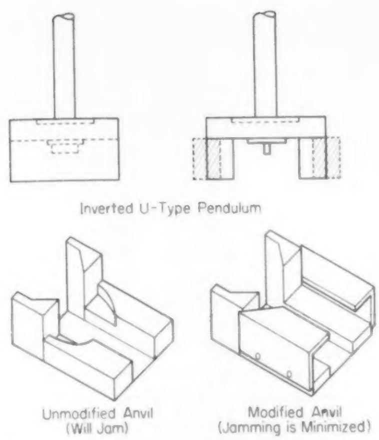


Fig. 5.—U-type pendulum and anvil assembly.

not sufficient, as variations of up to 10.0 ft-lb are commonly observed.

Although the span between the anvils is standardized at 1.574 ± 0.002 in., tests were conducted with the span length as the variable. Table II shows the effects when the span was varied by ± 0.025 in.

Alignment of Specimen Rests and Anvil Supports—The specimen rests and anvil supports must be in the same plane. At the same time they must be perpendicular to each other, or the specimen, when struck by the pendulum will spin and probably jam or will exhibit excessive brinelling. Either condition will slow down the pendulum and result in erroneously high energy values. There are some machines whose specimen rests are not sturdy, and if a specimen does jam, the rests easily bend out of position. It has been found that the normal practice is simply to hammer them back to approximate position with a lead hammer and continue testing. When this is done, the rests are out of alignment and additional jamming is almost certain.

Friction.—The procedure for determining friction losses are clearly outlined in ASTM Methods for Notched Bar Impact Testing of Metallic Materials.[2] Friction losses from other than windage and those which commonly cause erroneous energy values are from dirty or faulty bearings or indicating mechanisms or both.

Although excessive friction is undesirable, there must be sufficient friction in the indicating mechanism to ensure that it does not override the

TABLE II.—EFFECT OF CHANGING SPAN BETWEEN ANVILS.

Span, in.	High-Energy Specimens, ft-lb	Medium-Energy Specimens, ft-lb	Low-Energy Specimens, ft-lb
1.549......	78.3	51.8	13.3
1.574[a].....	76.0	49.7	12.7
1.599......	74.6	49.0	12.0

[a] Standard machine.

true value. This occurs particularly at high energy levels where the impact upon a ductile specimen may cause the indicating mechanism to override the actual value.

The pendulum-releasing mechanism may also cause excessive friction losses. Drag of the releasing unit on the rotating drum may cause a frictional loss of 5 ft-lb, particularly when lighter capacity pendulums are used (those of less than 100 ft-lb capacities at impact velocities of approximately 17 ft per sec).

Alignment and Condition of Pendulum and Striking Edge.—The distance between the center of contact and the center of percussion of the pendulum must be within ±1.0 per cent of the distance between the center of contact and the center of rotation. Also, the shaft must be so rigid that practically no vibrations will occur when the pendulum is released. To check the alignment of the pendulum, and more specifically of the striking edge, the front face of the striking edge of a freely hanging pendulum should just come to rest at the back side of a specimen in test position and make uniform contact (top to bottom). With the pendulum in this position, the energy indicator should record the capacity of the machine. After the friction is checked and the necessary corrections made, a free swing of the pendulum should indicate zero energy. If the energy indicator overrides zero energy and a looseness of the indicating mechanism parts is not found to be the cause, a close check will probably reveal the machine to be out of level, with the rear of the machine (end from which the pendulum falls) being high. If, on the other hand, the energy indicator does not reach zero on a free swing, there are two common causes: (1) the machine is out of level with the rear end low, or (2) the releasing mechanism is worn. In any case, the erroneous effect is more serious when tests are conducted on low-energy specimens, since the upper section of the indicating dial is used, and appropriate corrections must be made. An example of the error was obtained when tests were conducted after the angle from which the pendulum falls was lowered first by 1 and then by 2 deg, and the respective energy values were 13.5 and 14.1 ft-lb instead of the standard value of 12.5 ft-lb. Incidentally, the energy value should always be read from the dial before the pendulum is engaged for the next test, because the indicating dial may move while the pendulum is being locked.

[4] Reducing the thickness of the striking edge from $\frac{3}{4}$ to $\frac{3}{8}$ in. cannot be done in all machines. Only in those machines where the pendulum is the inverted U-type is this recommended since the clearance for the exit of the broken specimens is limited by the side plates (see Fig. 5). The $\frac{3}{4}$-in. thickness has not been found necessary in the other pendulums.

The releasing mechanism should also be checked to ensure that the pendulum releases evenly so as not to impart vibrations to the shaft as it is released. This would also raise the recorded energy.

The pendulum must pass through the anvils at the center with a minimum of side play and in a direction perpendicular to the specimen and anvil supports. Side play must not exceed 0.030 in.

Some machines are equipped with a brake which is engaged with the same lever used to release the pendulum. Experience has shown that the operator, when releasing the pendulum, may also engage the brake. This naturally would result in an erroneously high recorded energy value, since it slows the pendulum. To ensure that this will not occur with this particular releasing mechanism, it is recommended that a removable pin be installed between the release and brake position.

Elastic Energy Losses.—While investigating the effects of the different variables, it was found that several machines produced erroneously high energy values even though their dimensions were standard. These machines had capacities of 16, 30, and 60 ft-lb, respectively. The 16 and 30 ft-lb machines failed to break specimens usually requiring 12.5 ft-lb of energy; the 60 ft-lb machine broke the specimens, but with average energy values of 18 ft-lb. It was found that in all cases energy was being absorbed through the machine components. This absorption is in most cases in the anvil or pendulum assembly. Such components must be sufficiently rugged that the elastic deformation is not excessive during impact. This problem has been treated by Bluhm (**3**). It is this elastic energy loss that produces erroneously high recorded values.

General Comments

When conducting Charpy impact tests, the same testing procedure should be followed as for other mechanical tests, that is, all tests should be conducted in machines producing accurate, reproducible results, and consistent checks should be made on critical dimensions. If, for example, the extensometer used to measure strain in a tension or a compression test were found to produce an erratic strain, or if the daily check test with the test block on a hardness machine indicated it to be in error, then tests would be stopped until repairs were made and the machine rechecked. Why, then, don't the operators of Charpy impact testers, where the tests are at least equally dependent upon machine variables, consistently make dimensional checks on the critical parts and stop the tests if they are found in error? Serious inaccuracies may occur if Charpy tests are continued after jamming occurs. As soon as a jam has been detected, tests should be stopped until an examination of the mating parts indicates the machine to be in good condition. In Ordnance inspection tests, if a Charpy machine has jammed, it is required that testing be discontinued until an additional set of check specimens can be obtained from the respective Ordnance districts, tested, and the machine again certified as acceptable.

A machine inspected recently produced values of 40.0, 55.5, and 89.0 ft-lb instead of the required 12.5, 44.0, and 76.0 ft-lb. It was completely corrected with a single visit to the installation. The discrepancies noted and corrected were that the machine was not level or bolted, the anvil span was 1.570 in. instead of 1.574 ± 0.002 in., the anvil radii were 0.030 in. instead of 0.039 ± 0.001 in., the pendulum did not pass through the center of the anvils, the clearance at the end of the specimen was $\frac{1}{8}$ in. instead of $\frac{7}{16}$ in., a free swing of the pendulum indicated 2.0 ft-lb instead of zero, no shroud was used to contain the broken specimens, and the striking edge was $\frac{3}{4}$ in. instead of $\frac{3}{8}$ in. thick.[4]

Method of Machining and Finishing Test Specimens

Although a Charpy machine may be properly installed and accurately calibrated, the results of the tests will be only as accurate as the dimensions of the test specimen itself. The preparation of V-notch Charpy specimens involves three steps: machining the blanks, notching the specimens, and inspecting the finished bars for compliance with requirements. The first two steps have been adequately covered (**2, 4**). The inspection and effects of variables in critical dimensions will be discussed in some detail.

Before testing any specimens they should be closely inspected to ensure dimensional accuracy. This inspection must ensure that the specimen width, depth, length, and notch dimensions are within the allowable tolerances. Tests were conducted to determine the effects of relaxing some of the rigid dimensional tolerances.

Table III shows the effects of varying specimen dimensions. Note that reducing the specimen width decreases the energy to fracture, whereas reducing the specimen depth (the depth under the notch remaining constant at 0.315) in. increases the energy to fracture. The depth dimension has a greater effect on the resultant energy value (decreasing stress concentration).

Regarding the surface finish of the notch itself, it should be noted here that this aspect was also investigated. Through a series of strictly controlled experiments, it was found that a highly polished notch or a notch machined by

TABLE III.—EFFECTS OF VARYING SPECIMEN DIMENSIONS.

Variable	High-energy Specimens, ft-lb	Medium-energy Specimens, ft-lb	Low-energy Specimens, ft-lb
Specimen with standard dimensions	76.0 ± 3.8	44.5 ± 2.2	12.5 ± 1.0
0.005-in. machined off face opposite notch root[a]	78.1	45.2	12.6
0.010-in. machined off face opposite notch root[a]	79.3	45.9	13.2
0.025-in. machined off face opposite notch root[a]	84.5	46.2	14.0
0.010-in. machined off face adjacent to notch root	75.3	43.9	12.3
0.025-in. machined off face adjacent to notch root	74.0	39.1	11.7
Specimen out-of-square by 0.002 in.	76.3	43.6	13.1
Specimen out-of-square by 0.006 in.	77.5	44.5	13.0
Specimen out-of-square by 0.010 in.	77.0	44.6	13.0
Radius at base of notch, 0.005 in.[b]	72.3	41.7	10.8
Radius at base of notch, 0.015 in.[b]	80.0	47.4	15.8
Depth of notch, 0.085 in.[c]	72.2	41.3	11.5
Depth of notch, 0.0805 in.[c]	75.1	42.2	12.4
Depth of notch, 0.0775 in.[c]	76.8	45.3	12.7
Depth of notch, 0.074 in.[c]	79.6	46.0	12.8
Specimen with standard dimensions[d]	78.7 ± 3.9	34.6 ± 1.7	11.5 ± 1.0
Notch angle, 40 deg[e]	78.8	34.7	11.1
Notch angle, 50 deg[e]	77.5	34.7	11.4

[a] Distance under notch constant at 0.315 in. (standard).
[b] Standard 0.010 ± 0.001 in.
[c] Standard 0.079 ± 0.002 in.
[d] These specimens given different heat treatment.
[e] Standard 45 ± 1 deg.

standard milling operations had no effect on energy values for standard specimens. This point, however, should not be construed as allowing sloppiness in milling of the notch. Accurate dimensions must be complied with in order to meet test requirements.

The fact that a specimen is out-of-square will not in itself cause an erroneous energy reading; Table III shows specimens out-of-square by 0.010 in. producing values within the limits allowed. It should be pointed out, however, that the striking edge of the testing machine used was $\frac{3}{8}$ in. and the anvil assembly was free of side supports, so that even if spinning did occur, the accumulative dimensions of the broken specimens (diagonal dimensions) and the striking edge were still less than the span between the anvils. Since the squareness of the specimen does govern spinning in the broken specimens, and since the design of some machines is such that spinning may cause jamming unless certain extensive machine modifications are made, the maximum permissible tolerance for the standard specimens should remain at ±0.001 in. across the 0.394-in. width on approximately ±0 deg 10 min from 90 deg. A slope of not more than ±0 deg 10 min must also be adhered to if jamming is to be minimized.

A variation in the radius at the base of the notch will seriously affect the results of the tests. Note in Table III that a ±0.005-in. change in notch radius resulted in energy variations of approximately 5, 6, and 8 ft-lb, respectively, at the low, medium, and high energy levels

A ±0.005-in. change in notch depth is also noted to have harmful effects, particularly at higher energy levels; at the 75 ft-lb level the spread was 7.5 ft-lb.

The notch angle is not too critical. Tests indicate no serious energy variations from varying the angle of the notch by ±5 deg.

Although it has been shown that a variation in any one of many possible dimensional variations will not, in itself, necessarily cause erroneous energy values, it is not felt that the dimensional tolerances in ASTM Method E 23 can be relaxed, because a relaxation of any two quite likely would cause erroneous results.

Techniques of Cooling and Testing Specimens

The techniques of cooling and testing are given very little attention, and yet the erroneous values obtained from using incorrect techniques can be and often are greater than from many machine discrepancies. The procedure outlined by Driscoll (**2**), if carefully followed, will ensure that accurate techniques are being observed, but experience indicates this area to be the cause of many inaccuracies. For example, although published literature on proper testing techniques state that the test specimen must be so located in the machine that it is hit immediately behind the notch, an examination of the broken specimens used by those facilities attempting to qualify for Ordnance inspection tests showed that many specimens were hit off-center by amounts varying up to $\frac{1}{8}$ in. Tests conducted on specimens so machined that they would be hit off-center by $\frac{1}{8}$ in. produced values of 14.7, 47.2, and 86.8 ft-lb instead of the required 12.5, 44.5, and 76.0 ft-lb.

Some of the variables in cooling and testing techniques that can cause inaccuracies comparable to those resulting from inaccurate centering of the test specimen occur when: the specimens are not properly positioned in cooling containers; specimens are not at temperature for sufficient time; inaccurate thermometers are used; specimens are not accurately positioned in testing machine; excess time elapses between taking specimens from coolant and fracturing them; and the energy value is read from dial after, instead of before, engaging the pendulum.

Summary

When Charpy impact values are reported by various investigators, they may be in error by as much as 100 to 200 per cent at low-energy levels and 15 per cent at the upper energy levels. Many are unaware of the magnitude of the error that is possible and blame the inconsistencies on the test itself. It has been shown that most causes of erroneous values are such that they slow down the pendulum, and therefore the recorded energy values are erroneously high. The more significant causes of erroneous values are: improper installation of the machine itself; failure of the dimensions of the anvil supports and striking edge to be within the prescribed tolerances; excessive friction in moving parts; a general looseness of mating parts; insufficient clearance between the ends of the test specimen and the side supports; poorly machined test specimen; and improper cooling and testing techniques.

It was further noted that a machine can meet the standardized dimensional requirements and yet fail to fracture low-energy specimens even if the machine capacity is sufficient, or, if the specimen does fracture, the value is erroneously high. This indicates that the only satisfactory means of certifying a Charpy machine as acceptable is with standardized test specimens

It was also found that a variation in one of several dimensional tolerances in the machine or test specimens may not in itself necessarily cause erroneous results, but the effects of two or more may be cumulative and cause erroneous energy values. For this reason, it is felt that the dimensional tolerances as standardized by ASTM and others should not be relaxed.

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(**1**) D. E. Driscoll, "Reproducibility of Charpy Impact Test," Symposium on Impact Testing, *ASTM STP 176*, Am. Soc. Testing Mats., p. 70, 1955.

(**2**) D. E. Driscoll, "Calibration of the Charpy Impact Machine and Procedures for Inspecting and Testing of Charpy V-notch Impact Specimens," *Report WAL TR 112/89*, Watertown Arsenal Laboratories, Nov., 1958.

(**3**) J. I. Bluhm, "The Influence of Pendulum Flexibilities on Impact Energy Measurements," Symposium on Impact Testing, *ASTM STP 176*, Am. Soc. Testing Mats., p. 84, 1955.

(**4**) S. E. Siemen, "Method of Notching Impact Test Specimen," ASTM Bulletin, No. 139, March, 1946, p. 45.

Fracture Testing of High-Strength Sheet Materials

National Aeronautical and Space Administration—Naval Research Laboratory Cooperative Program on Specimens Intended for Fracture Toughness Measurements

Third Report of a Special ASTM Committee[1]

THE PURPOSE of this investigation was to establish accurately the type of notch specimen that should be used to measure fracture toughness of high-strength sheet materials.

The first report of the ASTM Committee on the Fracture Testing of High-Strength Materials (**1**)[2] described appropriate methods of stress analysis for K_c calculations using centrally notched and edge-notched specimens. This analysis was based on a description of the elastic stress field at a *crack* tip. However, the report suggested that a machined notch having a 0.001-in. maximum radius would adequately simulate the action of a crack, and that in any event the root radius was not important providing slow cracking preceded maximum load. However, no definite information was available to confirm these hypotheses.

Since the publication of the first committee report, much fracture-toughness testing has been undertaken by various organizations. Notch radii as high as 0.002 in. have been used by some investigators while others use fatigue cracks. Machined notches have been produced by various techniques including electrical-discharge machining, grinding, and tool cutting. The question, of course, arises as to whether or not the K_c values determined, using different types of specimens and different methods of notching, will be the same as those obtained using fatigue cracks.

Rather recently Morrison and Kattus (**2**) have introduced a specimen in which a central slot is made by shear punching. Such a specimen is much easier to produce than one containing a sharp notch or a fatigue crack. However, its suitability for K_c determinations has not been investigated previously.

This report considers the fracture toughness results obtained on three alloys in a cooperative program between the National Aeronautics and Space Administration (NASA) and the Naval Research Laboratory (NRL). The basic specimen types used included both central and edge notches produced by several processes, and the results are compared with data obtained for specimens having fatigue cracks. In addition, data are reported concerning the influence of notch radius, specimen width, notch preparation method, notching–heat-treating sequence, and some interactions of these factors. Sufficient data were available for several types of specimens to permit a statistical analysis of the variability of K_c values.

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[1] The ASTM Special Committee on Fracture Testing of High-Strength Materials is composed of the following members:

J. R. Low, Jr., Chairman, Research Laboratory, General Electric Co.
W. F. Brown, Jr., National Aeronautics and Space Administration
James Campbell, Battelle Memorial Inst.
R. H. Christensen, Douglas Aircraft Co.
T. J. Dolan, University of Illinois
R. H. Heyer, Armco Steel Co.
John Hodge, United States Steel Co.
G. R. Irwin, U. S. Naval Research Laboratory
J. E. Srawley, U. S. Naval Research Laboratory
C. F. Tiffany, Boeing Aircraft Co.
L. L. Wyman, National Bureau of Standards

In this program the following persons have assisted: A. G. Holms, National Aeronautics and Space Administration; J. M. Krafft, Naval Research Laboratory; and J. D. Morrison, Southern Research Inst.

[2] The boldface numbers in parentheses refer to the list of references appended to this paper.

TABLE I.—COMPOSITION AND PRODUCERS' TREATMENT OF TEST ALLOYS.

H-11 MODIFIED, FIRST HEAT

Vanadium Alloys Steel Co., H-11 modified heat No. 30625, sheets 1/16 by 24 by 72 in. cross-rolled from sheet bar.

Composition								
C (melt)	C (sheet)	Mn	P	S	Si	Cr	V	Mo
0.43	0.43	0.31	0.017	0.011	0.93	5.24	0.55	1.28

H-11 MODIFIED, SECOND HEAT

Composition							
C	Mn	P	S	Si	Cr	Mo	Ni
0.42	0.35	0.015	0.002	1.06	5.1	1.42	0.14

AISI 301-70 PER CENT COLD-ROLLED

American Steel and Wire Div., United States Steel Corp., heat No. 9 by 9343, cold-rolled strip, 1/16 in. thick by 24 in. wide, 70 per cent reduction.

Composition						
C (melt)	Mn	P	S	Si	Ni	Cr
0.10	1.24	0.033	0.020	0.53	7.28	17.16

B120 VCA

Crucible Titanium heat No. R6760, sheet No. 4T by 3, 1/16 by 36 by 102 in., solution treated 1450 F.

Composition						
C	Cr	V	N	Fe	Al	H
0.02	10.5	13.7	0.031	0.20	3.4	0.0075

Symbols

a = half of total notch length at start of rapid fracture, in.,
a_0 = half of total initial notch length, in.,
B = initial specimen thickness, in.,
K_c = fracture toughness, ksi $\sqrt{\text{in.}}$,
W = initial specimen gross width, in.,
ρ = notch root radius, in.,
σ_N = net stress (maximum load divided by net area at start of rapid fracture), ksi,
σ_{NS} = notch strength (maximum load divided by initial net area), ksi,
σ_{ut} = ultimate tensile strength, ksi, and
σ_{ys} = yield strength, ksi.

Material and Procedure

A heat-treated steel (H-11 modified), a cold-rolled stainless steel (AISI 301), and an aged titanium alloy (B120 VCA) were selected for this investigation. The composition and heat treatment for these materials are given in Tables I and II. These alloys represent rather widely different metallurgical structures and for this reason permit generalization of the conclusions with a reasonable degree of confidence.

Except for H-11 modified, all specimens were taken from a single sheet of

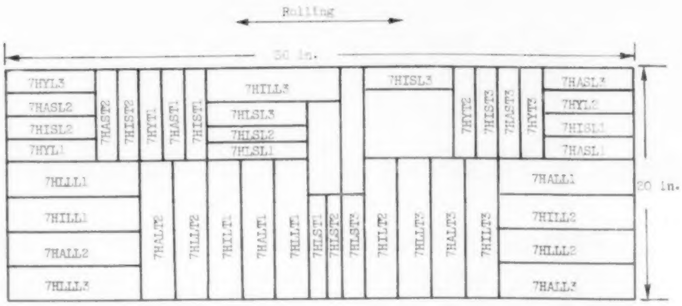


Fig. 1.—Stratified sampling of AISI 301, 70 per cent cold-rolled.

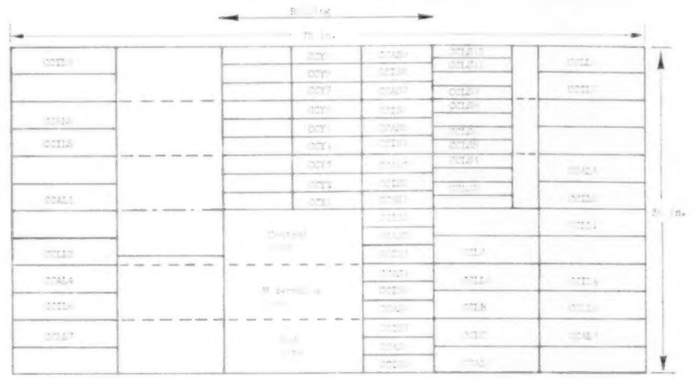


Fig. 2.—Stratified sampling of titanium alloy B120 VCA.

TABLE II.—SPECIMEN TYPES AND MATERIAL CONDITIONS INVESTIGATED.

Specimen type	Nominal width, in.	Notch radius, in.	Material	Process sequence N - notch H - heat treat	Specimens prepared by	Specimens tested by
Fatigue center crack	1.0 3.0 3.0 1.5 3.0 1.5	0 ↓	H-11 Mod. first heat ↓ H-11 Mod. second heat B120 VCA ↓ AISI 301-70% CR	N and H ↓ N and H; H and N N and H ↓ N	NRL - Srawley ↓ NRL - Irwin NRL - Srawley ↓	NRL - Srawley NASA NRL - Irwin NRL - Srawley NASA NRL - Srawley
Fatigue edge crack	1.0 3.0	0 ↓	H-11 Mod. second heat	N and H; H and N	NRL - Irwin ↓	NRL - Irwin ↓
Shear center crack	1.2, 1.3 3.0 1.3, 3.0 1.3, 3.0	0 ↓	H-11 Mod. first heat ↓ B120 VCA AISI 301-70% CR	N and H ↓ N	SRI ↓	NASA ↓
Electrical discharge center slot	3.0 ↓	0.0020 .0015 .0010 .0006 .0017 .0017 .0020	H-11 Mod. first heat ↓ H-11 Mod. second heat ↓ B120 VCA ↓ AISI 301-70% CR	N and H ↓ N and H; H and N H and N N and H N and H N	NRL - Irwin ↓	NRL - Irwin NASA NRL - Irwin ↓ NASA NRL - Irwin
Electrical discharge edge slot	1.0 ↓ 3.0 ↓	0.0006 .0010 .0030 .0006 .0010	H-11 Mod. second heat ↓	H and N H and N; N and H H and N H and N H and N; N and H	NRL - Irwin ↓	NRL - Irwin ↓
Ground edge notch	1.0 ↓	0.0010 .0020 .0040	H-11 Mod. second heat ↓	H and N ↓	NRL - Irwin ↓	NRL - Irwin ↓
Tool cut edge notch	1.0 3.0 1.0 3.0	0.0004 ↓	B120 VCA AISI 301-70% CR ↓	N and H N ↓	NASA ↓	NASA ↓

NOTE.—Fatigue crack specimens prepared by NRL (Srawley) were fatigued in tension-tension. Fatigue crack specimens prepared by NRL (Irwin) were fatigued by reverse flexing with bending moments perpendicular to the sheet plane. Specimens of H-11 modified were austenitized ½ hr in argon at 1850 F and triple 1-hr tempered in air at temperatures given in tables. Specimens of B120 VCA were aged 72 hr in argon at 900 F.

material. The sampling of AISI 301 and B120 VCA was stratified as shown in Figs. 1 and 2, respectively. The sampling of AISI 301 (Fig. 1) was designed to equalize the number of specimens of each type and size at the edges of the sheet. Longitudinal specimens were located at the ends of the sheet to maximize distance of fracture zones from possible end effects. The sampling of B120 VCA (Fig. 2) was designed to equalize the number of specimens of each type and size within the "central zone," the "midradius zone," and the "end zone." Two heats of H-11 modified were used. The first heat was employed for all tests except those for a special notch radius, notch preparation method, and notching–heat-treating sequence investigation performed at NRL. Specimens from the first heat were taken from three sheets with no particular sampling plan. The uniformity of this material is indicated by the hardness values reported in Table III. Two to four impressions were taken on each specimen. It will be noted that hardness at any tempering temperature varied by about two points Rockwell C. This uniformity in hardness suggests a corresponding uniformity in fracture characteristics. That is, the notch properties of H-11 modified are known to be a unique function of the tensile strength (**3**), and for heat-treated steels the tensile strength is a function of hardness.

The various specimen types and material conditions are summarized in Table II. The basic specimen types are illustrated in Fig. 3. A detailed description of these specimens, methods of preparation, and testing procedure has been given previously (**1,2**). With the exception of two series of special tests, all specimens were notched or fatigue-cracked before heat treatment. The H-11 modified was austenitized in argon and tempered in air. The B120 VCA was aged in argon.

The notch radii reported in Table II were determined using an optical comparator at 100×. The lower limit of resolution of this instrument is about 0.0002 in. Shear-punched specimens could not be examined in this manner, and no attempt was made to determine the slot end radius.

Analysis of Data

The slow crack lengths were determined by India ink staining (**1**). The K_c values were calculated using previously outlined methods (**1**) incorporating a correction for the size of the plastic zone at the crack tip. These values are reported in tabular form with sufficient information given to permit repeating the calculations. The reported data are results of computation from original measurements and are given to more figures than are justified by the measurements. This has been done to aid the reader who may wish to perform statistical computations or test other fracture theories without repeated introductions of rounding-off errors. Original dimensions were generally measured with a micrometer or a 100× comparator. The measurement of slow crack growth is discussed in a later section. The reproducibility of K_c measurements is discussed in the section presenting standard deviations. Values of K_c are currently not considered valid when yielding across the net section precedes unstable fracture, that is, when $\sigma_N/\sigma_{ys} > 1$). However, data not meeting this condition are reported in the tables for further study.

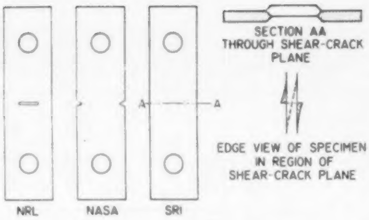


Fig. 3.—General arrangement of specimens. Dimensions entering K_c equations are given with tabular K_c data. Other dimensions were in accordance with reference (1).

When considering the data, differences in fracture toughness can be interpreted from two points of view: (1) a difference might or might not be important, or (2) it might or might not be significant. An important difference is one that represents practical differences in component performance. The designer or project engineer must be the judge of whether a difference is important. A significant difference is one that is larger than any difference that might be expected from a chance combination of small random errors. The mechanical metallurgist or the statistician must be the judge of whether a difference is significant. Because the point of view of the designer or project engineer must vary with the application, the data will be interpreted here from the point of view of differences that are real when compared with the random scatter, that is, differences that are significant.

Comparison of Various Specimen Types Using Three Alloys

Consideration will be given first to the results obtained for H-11 modified (first heat), AISI 301, and B120 VCA using central fatigue crack, central shear punch, central electrical-discharge slot, and tool-cut edge notch, all specimens notched and then heat treated. Results obtained on the second heat of H-11 modified for the effects of notch radius, specimen width, notch method, and notching–heat-treating sequence will be considered separately.

H-11 Modified

The results for the first heat of H-11 modified tempered at various temperatures are given in Table IV. This table shows that both widths of the shear-punched specimen and the 3-in. wide edge-notch specimen gave the same K_c values as were obtained using central fatigue cracks. In contrast, the K_c values for the 1-in.-wide edge-notch specimens and the 3-in.-wide electrical-discharge slot (0.002 in. maximum radius) were significantly higher than those obtained using central fatigue cracks. These differences were greatest for the 1000 F temper and larger for the specimen with the central electrical-discharge slot. At tempering temperatures above or below 1000 F, the differences in K_c between the various specimen types tended to become smaller.

B120 VCA

Results for B120 VCA are given in Table V. In contrast to the results for H-11 alloy, much closer agreement in K_c values is observed among the various specimen types. Both edge-notched specimen types yielded the same fracture toughness, which is significantly lower than that obtained using central-notch specimens. This difference might be due to bending moments in the plane of the sheet resulting from asymmetrical slow crack development in the edge-notch specimens. This latter type of specimen generally exhibited a greater degree of asymmetry in this respect than did the central-notch specimen.

AISI 301, 70 Per Cent Cold Reduced

Results for AISI 301, using the same series of specimens as for the first heat of H-11 modified, are shown in Table VI. This steel exhibited higher toughness in the longitudinal direction—several of the specimen types yielded across the net section before the onset of rapid fracture. A comparison of specimen types, therefore, must be confined to the transverse direction. For tests in this

TABLE III.—AVERAGE SPECIMEN HARDNESS VALUES FROM THREE SHEETS OF FIRST HEAT OF H-11 MODIFIED.

	Triple Tempering Temperature, deg Fahr				
	900	1000	1075	1100	1125
Number of specimens	18	30	17	21	18
Minimum Rockwell C	57.4	55.8	51.7	49.0	46.8
Maximum Rockwell C	58.7	57.9	53.7	51.4	48.5
Range, Rockwell C	1.3	2.1	2.0	2.4	1.7

TABLE IV.—FRACTURE TOUGHNESS

Specimen type	Nominal width, in.	Triple one hour temper, 900 F: σ_{ys} = 230 kpsi, σ_{ut} = 321 kpsi								Triple one hour temper, 1000 F: σ_{ys} = 223 kpsi, σ_{ut} = 311 kpsi								Triple one hour	
		Specimen number	$2a_o/W$	σ_{NS}/σ_{ut}	a/a_o	Percent shear	σ_N/σ_{ys}	K_c *	Mean K_c	Specimen number	$2a_o/W$	σ_{NS}/σ_{ut}	a/a_o	Percent shear	σ_N/σ_{ys}	K_c *	Mean K_c	Specimen number	$2a_o/W$
Fatigue center crack	3.0									V466	0.330	0.115	1.000	6.5	0.161	31.9			
										V493	.328	.118	1.000	5.5	.164	32.2			
										V496	.330	.113	1.000	5.3	.157	30.8	31.6		
	1.0	V421	0.319	0.177	1.084	5	0.257	30.4		V423	.319	.199	1.000	8	.278	31.7		V424	0.315
		V422	.315	.187	1.123	9	.277	32.9		V429	.293	.179	1.235	8	.276	31.8		V426	.314
		V428	.320	.187	1.128	5	.277	32.9	32.1	V434	.320	.211	1.026	10	.298	34.1	32.5	V431	.330
Shear center crack	3.0	V447	0.340	0.119	1.000	5.5	0.166	33.8		V460	0.339	0.129	1.012	8.1	0.180	35.6		V445	0.339
		V448	.340	.117	1.000	5.6	.163	33.1		V462	.339	.130	1.000	8.3	.181	35.7		V446	.339
		V450	.339	.111	1.000	4.7	.155	31.6	32.8	V464	.339	.133	1.000	8.0	.185	36.4	35.9	V461	.339
	1.2	V467	.361	.157	1.000	4.0	.219	28.3		V468	.367	.170	1.000	7	.237	29.8		V469	.364
	1.3	V482	.338	.165	1.000	4.4	.231	30.9		V475	.334	.168	1.000	6	.234	30.3		V474	.337
	1.3	V488	.336	.150	1.000	3.9	.210	28.1		V483	.336	.163	1.000	6	.227	29.4		V484	.338
	1.2									V470	.364	.190	1.000	8	.264	33.3			
	1.2									V476	.363	.187	1.000	6	.261	32.8			
	1.3									V485	.363	.204	1.000	6	.284	35.9			
	1.3									V473	.337	.187	1.000	7.5	.260	33.8			
	1.3								29.1	V480	.338	.189	1.000	7	.263	34.3	32.5		
Electrical discharge center slot	3.0	V395	0.307	0.151	1.152	7	0.227	46.3		V401	0.307	0.332	1.109	24	0.487	99.0		V404	0.307
		V397	.307	.138	1.250	9	.217	44.5		V411	.307	.262	1.087	22	.380	76.0		V408	.307
		V414	.307	.166	1.109	8	.243	49.6	46.8	V412	.307	.221	1.141	20	.329	65.7	80.2	V409	.307
										V491	.302	.369	1.000	15	.515	103.9			
										V494	.307	.245	1.000	10	.342	67.5			
										V497	.305	.129	1.000	7	.179	34.8	68.7		
Tool cut edge notch	3.0	V435	0.298	0.0932	1.040	5.8	0.132	28.4		V440	0.299	0.111	1.023	8.2	0.156	32.6		V439	0.300
		V456	.298	.0994	1.000	6	.139	29.7		V449	.299	.111	1.000	6.3	.155	32.3		V454	.298
		V457	.298	.0956	1.014	6	.134	28.8	29.0	V455	.298	.124	1.000	9.2	.174	36.2	33.7	V465	.299
	1.0	76	.302	.180	1.000	4.2	.251	31.5		89	.300	.280	1.251	12	.438	54.8		V303	.297
		V301	.299	.168	1.132	5.6	.249	31.4		92	.300	.294	1.165	11.8	.441	55.3		V306	.300
		V309	.298	.143	1.204	4.5	.218	27.6		93	.300	.315	1.225	13	.487	61.4		V307	.298
										V302	.298	.252	1.179	11.8	.380	47.3		V311	.298
										V305	.297	.255	1.179	13	.385	47.9			
										V477	.302	.314	1.000	14	.438	54.4			
										V478	.301	.337	1.000	14	.470	58.7			
										V489	.301	.338	1.000	11.5	.472	58.9			
								30.2		V490	.299	.312	1.000	11	.435	53.9	54.7		

[a]K_c not computed when argument, θ, of tan function in K_c equation is larger than θ of $\tan(\theta) = 10^{38}$.
[b]Slots extended after heat treatment.

* ksi$\sqrt{\text{in.}}$

TABLE V.—FRACTURE TOUGHNESS RESULTS FOR TITANIUM ALLOY B-120 VCA AGED 72 HR AT 900 F.

σ_{ys} = 196 ksi σ_{ut} = 211 ksi

Specimen type	Nominal width, in.	First heat treat batch								Second heat treat batch							
		Specimen number	$2a_c/W$	σ_{NS}/σ_{ut}	a/a_c	Percent shear	σ_N/σ_{ys}	K_c *	Mean K_c	Specimen number	$2a_c/W$	σ_{NS}/σ_{ut}	a/a_c	Percent shear	σ_N/σ_{ys}	K_c *	Mean K_c
Fatigue center crack	3.0									CCLA	0.250	0.173	1.748	25	0.247	43.2	
										CCLB	.262	.188	1.544	28	.251	44.1	
										CCLC	.264	.181	1.546	23	.242	42.5	43.3
	1.5	CCLS4[a]	0.334	0.226	1.627	17	0.355	42.2		CCLS2	.352	.213	1.939	23	.467	49.4	
		CCLS5[a]	.336	.228	1.653	15	.365	43.2		CCLS6	.329	.232	1.626	26	.360	43.1	
		CCLS9[a]	.334	.224	1.627	22	.351	41.8		CCLS8	.338	.216	1.874	24	.420	46.8	
										CCLS11	.333	.227	1.904	23	.443	49.6	
									42.4	CCLS12	.337	.231	1.759	23	.405	46.8	47.1
Shear center crack	3.0	CCIL2	0.345	0.128	1.696	13.4	0.217	35.4		CCIL5	0.347	0.141	1.788	16	0.260	41.0	
		CCIL4	.345	.122	1.770	12.9	.221	35.2		CCIL6	.343	.133	1.906	19	.272	41.6	
		CCIL9	.347	.148	1.723	20.3	.258	41.6	37.4	CCIL7	.344	.151	1.879	20	.261	40.1	40.9
	1.3	CCIS1	.344	.157	1.900	11.6	.318	32.1		CCIS2	.344	.138	2.167	17	.382	34.0	
		CCIS5	.344	.132	2.102	16.6	.335	30.8		CCIS3	.344	.140	2.240	18	.423	36.6	
		CCIS8	.344	.134	1.974	12.9	.336	33.0		CCIS4	.346	.145	2.134	18	.369	35.1	
										CCIS6	.347	.136	2.219	21	.413	35.3	
										CCIS7	.344	.135	2.173	16	.376	33.4	
									32.0	CCIS9	.340	.150	2.198	16	.417	37.2	35.3
Electrical discharge center slot	3.0	CCLL2[b]	0.310	0.196	1.387	9	0.255	44.6		CCLL1	0.303	0.192	1.427	23	0.253	44.4	
		CCLL6[b]	.313	.183	1.362	10	.235	41.0		CCLL5	.306	.189	1.549	26	.268	46.5	
		CCLL7[b]	.313	.214	1.309	9	.267	46.9	44.2	CCLL9	.308	.203	1.387	22	.264	46.3	45.7
Tool cut edge notch	3.0	CCAL3	0.297	0.148	1.321	15.2	0.183	34.0		CCAL1	0.297	0.156	1.359	15	0.198	36.7	
		CCAL4	.297	.149	1.335	14.8	.186	34.5		CCAL5	.297	.152	1.294	22	.187	34.6	
		CCAL9	.297	.143	1.344	14.4	.180	33.3	33.9	CCAL7	.297	.156	1.236	22	.198	34.5	35.3
	1.0	CCAS1	.300	.233	1.673	14.3	.351	36.7		CCAS2	.301	.262	1.464	23	.351	37.8	
		CCAS4	.301	.227	1.490	10.4	.309	33.0		CCAS3	.299	.240	1.439	21	.317	34.1	
		CCAS8	.300	.225	1.646	13.4	.335	35.1		CCAS5	.301	.236	1.398	19	.306	32.9	
										CCAS6	.300	.234	1.470	21	.314	33.6	
										CCAS7	.301	.239	1.566	19	.340	36.1	
									34.9	CCAS9	.300	.226	1.584	22	.324	34.3	34.8

[a] Specimens tested by NRL Metallurgy Div. and ink stains measured at NASA.
[b] Specimens tested and ink stains measured by NRL Mechanics Div.
All other specimens tested and ink stains measured at NASA.

* ksi$\sqrt{\text{in.}}$

RESULTS FOR FIRST HEAT OF H-11 MODIFIED

σ_{NS}/σ_{ut}	a/a_o	Percent shear	σ_N/σ_{ys}	K_c *	Mean K_c
...emper, 1075 F: σ_{ys} = 214 kpsi, σ_{ut} = 261 kpsi					
0.470	1.377	28	0.693	81.4	
.501	1.044	28	.623	72.0	
.399	1.112	28	.515	58.6	70.7
0.355	1.000	25	0.433	83.9	
.255	1.000	20	.311	59.5	
.233	1.000	15	.284	54.2	65.9
.378	1.000	22	.461	57.0	
.508	1.000	30	.619	81.5	
.357	1.000	20	.435	55.4	
				—	64.6
0.397	1.130	45	0.514	100.9	
.414	1.130	48	.536	105.6	
.420	1.109	50	.538	105.9	104.1
0.272	1.000	32	0.332	67.3	
.258	1.021	28	.317	64.4	
.244	1.015	25	.300	60.8	
				—	64.2
.533	1.326	90	.753	96.6	
.499	1.195	33	.664	83.6	
.543	1.312	40	.764	98.4	
.525	1.371	42	.759	97.1	
				—	93.9

Specimen number	$2a_o/W$	σ_{NS}/σ_{ut}	a/a_o	Percent shear	σ_N/σ_{ys}	K_c *	Mean K_c
Triple one hour temper, 1100 F: σ_{ys} = 202 kpsi, σ_{ut} = 242 kpsi							
V418	0.314	0.852	1.625	95	1.429	a	
V425	.321	.812	1.516	90	1.286	a	
V432	.335	.704	1.655	90	1.258	a	a
V444	0.339	0.692	1.257	85	0.955	201.8	
V459	.339	.661	1.328	90	.951	199.3	
V463	.340	.604	1.327	80	.870	175.5	192.2
V471	.365	.839	1.201	100	1.137	181.0	
V479	.336	.754	1.364	100	1.107	172.4	
						—	176.7
V400[b]	0.407	0.682	1.279	86	1.010	211.6	
V402[b]	.400	.690	1.317	94	1.048	224.8	
						—	218.2
V436	0.299	0.646	1.205	94	0.848	184.9	
V451	.299	.608	1.218	90	.803	171.9	
V452	.302	.496	1.235	85	.665	136.4	
V492	.298	.458	1.355	87	.646	131.2	
V498	.297	.482	1.271	62	.652	133.0	151.5
67	.301	.672	1.584	100	1.075	149.3	
78	.301	.747	1.275	100	1.016	139.6	
88	.300	.820	1.361	100	1.163	a	
101	.301	.822	1.295	100	1.127	180.3	
						—	a

Specimen number	$2a_o/W$	σ_{NS}/σ_{ut}	a/a_o	Percent shear	σ_N/σ_{ys}	K_c *	Mean K_c
Triple one hour temper, 1125 F: σ_{ys} = 185 kpsi, σ_{ut} = 224 kpsi							
V427	0.314	0.895	1.400	100	1.328	a	
V430	.317	.883	1.440	100	1.344	a	
V433	.326	.891	1.428	100	1.361	a	a
V443	0.339	0.801	1.328	100	1.165	a	
						—	a
V472	.364	.909	1.195	100	1.239	a	
V481	.336	.890	1.270	100	1.261	a	
V487	.337	.898	1.200	100	1.211	a	
						—	a
V405	0.407	0.791	1.279	100	1.184	a	
						—	a
V437	0.299	0.743	1.235	100	1.000	216.1	
V441	.299	.709	1.202	100	.940	196.1	
V453	.299	.692	1.236	100	.931	192.8	
V438	.299	.746	1.286	100	1.030	226.5	
V495	.298	.685	1.261	87	.932	193.0	204.9
69	.302	.851	1.254	100	1.158	a	
V304	.298	.924	1.431	100	1.369	a	
V308	.298	.917	1.374	100	1.319	a	
V312	.299	.903	1.319	100	1.266	a	
						—	a

TABLE VI.—FRACTURE TOUGHNESS RESULTS FOR AISI 301, 70 PER CENT COLD REDUCTION.

Specimen type	Nominal width, in.	Transverse:[a] σ_{ys} = 227.2 kpsi; σ_{ut} + 260.2 kpsi							Longitudinal:[b] σ_{ys} = 220.3 kpsi; σ_{ut} = 250.9 kpsi						
		Specimen number	$2a_o/W$	σ_{NS}/σ_{ut}	a/a_o	σ_N/σ_{ys}	K_c *	Mean K_c	Specimen number	$2a_o/W$	σ_{NS}/σ_{ut}	a/a_o	σ_N/σ_{ys}	K_c *	Mean K_c
Fatigue center crack	1.5	7HLST1	0.333	0.479	1.643	0.807	120.0		7HLSL1	0.333	0.714	1.531	1.106	196.3	
	↓	7HLST2	.327	.480	1.686	.823	122.7		7HLSL2	.330	.704	1.511	1.072	183.2	
		7HLST3	.333	.475	1.547	.749	112.3	118.3	7HLSL3	.328	.724	1.291	.961	157.0	178.8
Shear center crack	3.0	7HILT1	0.346	0.590	1.116	0.719	157.3		7HILL1	0.346	0.808	1.066	0.954	221.0	
	↓	7HILT2	.341	.613	1.123	.750	165.3		7HILL2	.342	.705	1.072	.834	183.2	
		7HILT3	.345	.599	1.140	.741	162.8	161.8	7HILL3	.347	.754	1.066	.890	200.1	201.4
	1.3	7HIST1	.348	.743	1.419	1.095	186.6		7HISL1	.348	.904	1.268	1.202	c	
	↓	7HIST2	.352	.741	1.347	1.045	170.5		7HISL2	.346	.918	1.185	1.160	c	
		7HIST3	.348	.715	1.490	1.109	190.0	182.4	7HISL3	.348	.911	1.261	1.205	c	c
Electrical discharge center slot	3.0	7HLLT1	0.305	0.377	1.522	0.560	117.1		7HLLL1	0.307	0.599	1.663	0.966	216.1	
	↓	7HLLT2	.307	.401	1.293	.528	110.8		7HLLL2	.307	.674	1.326	.897	201.6	
		7HLLT3	.307	.376	1.522	.560	116.6	114.8	7HLLL3	.307	.651	1.500	.952	216.5	211.4
Tool cut edge notch	3.0	7HALT1	0.299	0.339	1.318	0.449	99.0		7HALL1	0.298	0.538	1.441	0.753	169.9	
	↓	7HALT2	.298	.352	1.322	.466	103.1		7HALL2	.297	.615	1.269	.790	183.1	
		7HALT3	.298	.334	1.282	.435	95.9	99.3	7HALL3	.298	.591	1.297	.770	176.9	176.6
	1.0	7HAST1	.304	.491	1.495	.717	94.6		7HASL1	.304	.722	1.498	1.051	157.1	
	↓	7HAST2	.305	.587	1.403	.817	112.3		7HASL2	.305	.766	1.445	1.082	169.0	
		7HAST3	.303	.486	1.518	.718	94.4	100.4	7HASL3	.301	.785	1.608	1.211	c	c

[a] Laminated surface of fracture prevented quantitative measurement of per cent shear. * ksi $\sqrt{\text{in.}}$

[b] All fracture surfaces showed 100 per cent shear.

[c] Argument, θ, of tangent function larger than θ of tan (θ) = 10^{33}.

direction all types except shear-punched specimens give nearly the same value of K_c. As was observed for B120 VCA, the K_c values for edge-notch specimens are somewhat lower than for specimens with central fatigue cracks or central electrical-discharge slots. Again, this might be explained by bending stresses.

The shear-punched specimens showed considerably higher K_c values than the other types. This is in contrast to the behavior of these specimens when testing H-11 and B120 VCA. The reason for this difference in behavior of shear-punched specimens with change of material is not known. The shear-punched specimen is deformed by the punching operation so that the material in the vicinity of the slot is not in the original sheet plane. (Dial-indicator measurements did not reveal any significant differences among the contours produced in the three alloys.) This out-of-plane condition would introduce a different loading condition at the slot tip than was encountered in the other specimen types. In the case of the AISI 301, the result is a specimen unsuitable for K_c determination.

Effect of Notch Radius, Specimen Width, Notch Fabrication, and Notching–Heat-Treating Sequence

Central- and edge-notch specimens were prepared from a second heat of H-11 modified. These specimens were used in a program at NRL designed to yield a better understanding of factors contributing to large K_c differences among various specimen types observed for tests on the first heat of this alloy. These differences were largest for the 1000 F temper (see Table IV), and this temper was therefore selected for specimens of the second heat. Specific factors investigated were: (1) notch root radius, (2) specimen width, (3) method of fabricating the notch, and (4) notching–heat-treating sequence.

The resulting data for 1-in.-wide edge-

TABLE VII.—EFFECT OF EDGE NOTCH ROOT RADIUS ON MEASURED FRACTURE TOUGHNESS. SECOND HEAT OF H-11 MODIFIED. 1-IN. WIDE SPECIMENS TRIPLE 1-HR TEMPERED AT 1000 F FOLLOWED BY NOTCHING.

Stress raiser	Specimen number	ρ, notch root radius, in.	$\sqrt{\rho}$	$2a_o/W$	σ_{NS}/σ_{ut}	a/a_o	Percent shear	σ_N/σ_{ys}	K_c *	Mean K_c
Fatigue edge crack	1275	0	0	0.380	0.207	1.105	6	0.299	37.8	
	1276			.420	.102	1.071	6	.145	18.0	
	1277			.410	.145	1.024	5	.199	25.0	26.9
Electrical discharge edge notch	1272	.0006	.0245	.300	.281	1.267	6	.429	55.3	
	1273			.300	.118	1.333	5	.187	23.5	
	1274			.300	.203	1.333	5	.320	40.7	39.8
Electrical discharge edge notch	1269	.0010	.0316	.300	.355	1.400	9	.579	75.9	
	1270			.300	.287	1.667	6	.543	68.2	
	1271			.300	.337	1.467	7	.570	74.1	72.7
Ground edge notch	1278	.0010	.0316	.316	.300	1.333	7	.479	60.2	
	1279			.316	.306	1.333	6	.489	61.5	
	1280			.316	.315	1.367	6	.513	64.5	62.1
Ground edge notch	1281	.0020	.0447	.316	.425	1.533	10	.763	98.8	
	1282			.313	.516	1.500	7	.902	124.6	
	1283			.316	.513	1.433	9	.867	118.4	113.9
Electrical discharge edge notch	1287	.0030	.0548	.316	.516	1.433	10	.872	119.3	
	1288			.300	.482	1.367	10	.773	106.6	
	1289			.300	.482	1.600	12	.877	121.4	115.8
Ground edge notch	1284	.0040	.0632	.313	.564	1.433	10	.949	135.7	
	1285			.316	.579	1.500	9	1.017	148.6	
	1286			.316	.572	1.433	8	.967	138.6	141.0

* ksi $\sqrt{\text{in.}}$

TABLE VIII.—EFFECT OF EDGE NOTCH ROOT RADIUS ON MEASURED FRACTURE TOUGHNESS. SECOND HEAT OF H-11 MODIFIED. 1-IN. WIDE SPECIMENS NOTCHED FOLLOWED BY AUSTENITIZING AND TRIPLE 1-HR TEMPERING AT 1000 F.

Stress Raiser	Specimen Number	ρ, Notch Root Radius, in.	$\sqrt{\rho}$	$2a_0/W$	σ_{NS}/σ_{ut}	a/a_0	Per Cent Shear	σ_N/σ_{ys}	K_c ksi $\sqrt{\text{in.}}$	Mean K_c
Fatigue edge crack	1248	0	0	0.340	0.155	1.088	6	0.219	27.6	...
	1249	...	...	0.340	0.193	1.088	5	0.273	34.6	...
	1250	...	...	0.370	0.123	1.189	5	0.187	23.3	...
	...	...	...	...	...	...	...	...	...	28.5
Electrical discharge edge notch	1245	0.0010	0.0316	0.300	0.425	1.667	7	0.804	107.2	...
	1246	...	...	0.300	0.423	1.667	7	0.801	106.7	...
	1247	...	...	0.300	0.343	1.500	6	0.590	76.6	...
	...	...	...	...	...	...	...	...	...	96.8

TABLE IX.—FRACTURE TOUGHNESS RESULTS FOR 3-IN. WIDE SPECIMENS OF SECOND HEAT OF H-11 MODIFIED TEMPERED AT 1000 F.

Stress type	Notched before heat treatment										Heat treatment before notching							
	ρ, notch root radius, in.	$\sqrt{\rho}$	Specimen number	$2_{NS}/W$	σ_{ao}/σ_{ut}	a/a_o	Percent shear	σ_N/σ_{ys}	K_c *	Mean K_c	Specimen number	$2a_o/W$	σ_{NS}/σ_{ut}	a/a_o	Percent shear	σ_N/σ_{ys}	K_c *	Mean K_c
Fatigue center crack	0	0	1236	0.307	0.102	1.022	0	0.140	28.0		1258	0.380	0.098	1.035	0	0.136	27.8	
			1237	.302	.111	1.022	0	.151	30.6		1259	.467	.099	1.014	0	.135	27.3	
			1238	.323	.106	1.072	0	.148	30.1	29.6								27.6
Electrical discharge center slot	.0006	.0245									1254	.305	.167	1.211	0	.249	50.7	
											1255	.300	.157	1.122	7	.223	45.4	
											1256	.300	.176	1.056	6	.244	49.3	48.5
Electrical discharge center slot	.0010	.0316	1233	.300	.290	1.111	0	.412	85.4		1251	.300	.246	1.200	9	.364	75.4	
			1234	.300	.233	1.111	0	.330	67.7		1252	.300	.257	1.133	9	.368	76.0	
			1235	.300	.241	1.222	10	.360	74.7	75.9	1253	.300	.221	1.178	0	.323	66.6	72.7
Fatigue edge crack	0	0	1242	0.310	0.061	1.075	0	0.071	15.4		1266	0.427	0.0936	1.016	0	0.128	27.6	
			1243	.310	.104	1.011	0	.141	30.5		1267	.350	.0929	1.038	5	.128	27.9	
			1244	.310	.088	1.075	0	.123	26.6	24.2								27.8
Electrical discharge edge notch	.0006	.0245									1263	.300	.142	1.056	5	.197	42.7	
											1264	.300	.143	1.078	4	.201	43.6	
											1265	.300	.140	1.078	5	.195	42.4	42.9
Electrical discharge edge notch	.0010	.0316	1239	.300	.097	1.167	0	.142	30.8		1260	.300	.197	1.089	6	.276	60.4	
			1240	.300	.136	1.078	0	.190	41.4		1261	.300	.152	1.111	7	.215	46.9	
			1241	.300	.246	1.022	0	.336	73.5	48.6	1262	.300	.191	1.056	6	.264	57.5	54.9

* ksi $\sqrt{\text{in.}}$

TABLE X.—INTERACTION OF WIDTH AND EDGE NOTCH RADIUS ON K_c VALUES. SECOND HEAT OF H-11.

Process Sequence	Stress Raiser	Notch Radius, in.	Mean K_c, 3.0 in. Nominal Width, ksi $\sqrt{in.}$	Mean K_c, 1.0 in. Nominal Width, ksi $\sqrt{in.}$
Notch and heat treat	Fatigue edge crack	0	24.2	28.5
	Electrical discharge edge slot	0.0010	48.6	96.8
Heat treat and notch	Fatigue edge crack	0	27.8	26.9
	Electrical discharge edge slot	0.0010	54.9	72.7

TABLE XI.—RESULTS OF ANALYSIS OF VARIANCE CALCULATION.

Effect	Descriptive Significance Level
Notch radius	<0.005
Specimen width	<0.005
Notching and heat treating sequence	0.4
Sequence-radius interaction	0.3
Sequence-width interaction	0.08
Radius-width interaction	<0.005
Radius-width-sequence interaction	0.2

notch specimens notched after heat treatment to several radii and by three fabrication processes is given in Table VII. Similar but fewer data for the notch–heat-treat sequence are given in Table VIII. Comparable data for 3-in.-wide central- and edge-notch specimens are given in Table IX.

An objective separation of significant from nonsignificant factors was provided by a fixed-effects analysis of variance calculation. For this purpose, the maximum amount of data that could be used in an elementary analysis was extracted from Tables VII, VIII, and IX. These data consisted of the individual values of K_c for which mean values have been listed in Table X. Results of the calculation are expressed in terms of the descriptive significance level in Table XI.

The descriptive significance level is the probability that a variation of K_c as large or larger than that observed in the sample is simply the result of a chance combination of small random errors, that is, a combination of small factors that have not been accounted for. When this probability is small (less than 5 per cent or preferably 1 per cent) statisticians say that the observed effect should be attributed to the existence of a real systematic influence present in the population sampled. Correspondingly, Table XI implies that there is a real effect of notch radius, a real effect of specimen width, and a real interaction between notch radius and specimen width (the influence of width changes when the notch radius changes). All other factors (including the notching–heat-treating sequence, which might depend on the heat treating atmosphere and the alloy) failed to appear as significant and will not be discussed further. The factors that showed up as significant will be examined with the aid of data additional to those in Tables X and XI.

Notch Radius

The greatest variation in notch root radius was achieved for the 1-in.-wide heat-treated and edge-notched specimens. The corresponding K_c data have been plotted in Fig. 4(a) as a linear function of the square root of the notch radius. Some investigators have reported K_c values from tests with notch radii as large as 0.002 in. Figure 4(a) shows that such a radius can give values of K_c of three to four times the true (fatigue crack) value.

A horizontal line has been drawn through the mean value of the fatigue crack data of Fig. 4(a), and a sloping line has been fitted by the method of least squares to all of the remaining data. The intersection of the two lines occurs at a notch root radius of 0.00025 in., suggesting that machined notches must have a radius less than $\frac{1}{4}$ mil to measure a K_c that could represent a natural crack. Table VIII presents data for the notching followed by heat-treating sequence, and these data are consistent with the heat-treat and notch data of Fig. 4(a).

Data from 3-in. wide specimens heat-treated and edge-notched have been plotted as Fig. 4(b), and data from 3-in.-wide specimens heat-treated and central-slotted have been plotted as Fig. 4(c). Curve fitting similar to that used in Fig. 4(a) shows maximum permissible radii of 0.00024 in. and 0.00034 in., respectively. The data of Figs. 4(b) and (c) thus support the conclusion of Fig. 4(a), namely, for the given condition of material, the maximum allowable machined notch radius is $\frac{1}{4}$ mil.

Irwin (**4**) has suggested that the upper limit of notch radius for K_c determinations is approximately one tenth the size of the crack tip plastic zone. The expression for the plastic zone size, r_y, as given by Irwin is:

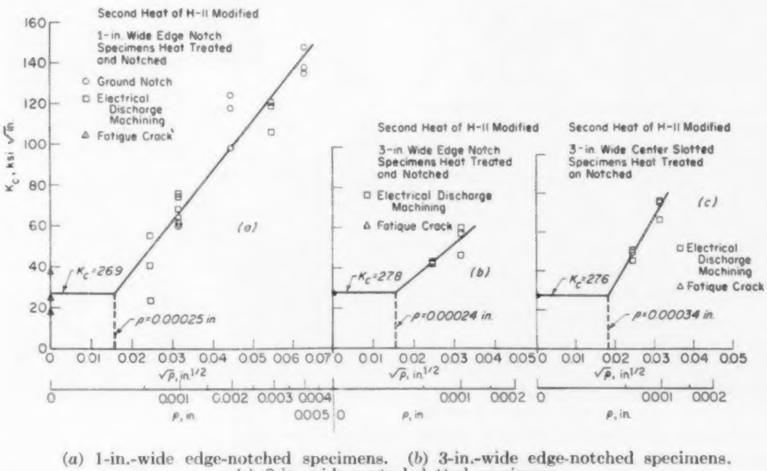
$$r_y = \frac{K_c^2}{2\pi\sigma_{ys}^2} = \frac{1}{2\pi}\left(\frac{26.9}{230}\right)^2 = 0.00217$$

and the corresponding limiting radius is 0.000217 in., which is consistent with the limit of $\frac{1}{4}$ mil from Fig. 4(a).

These results for the influence of notch radius on H-11 modified are in contrast to conclusions regarding the radius effect which can be made on the basis of previously discussed data for B120 VCA and AISI 301 (see Tables V and VI). For these two materials, the 0.002-in. radius electrical-discharge-machined central slot gave K_c values in good agreement with those calculated for specimens containing central fatigue cracks. Thus, the influence of notch radius depends on the material investigated. It might be expected that alloys that tend to form pronounced slow cracks under rising load would show less dependence on notch radius than those which develop little or no such cracks.

Effect of Width and Interaction of Width and Radius

The fatigue-crack specimens (Table X) show no significant effect of width. However, the data of Table X suggest that higher K_c values are obtained with narrow specimens when the notch radius is 0.001 in. In other words, the significance shown for the average width effect (Table XI) is entirely due to the width effect of the 0.001-in-radius specimens. The interaction between width



(a) 1-in.-wide edge-notched specimens. (b) 3-in.-wide edge-notched specimens. (c) 3-in.-wide central-slotted specimens.

Fig. 4.—Variation of K_c with root radius.

and radius that was shown to be significant in Table XI is seen to consist of no effect of width for the fatigue-crack specimens and a major effect of width for specimens with a 0.001-in. radius notch. The same interaction is exhibited by the steeper slope of the fitted line for 1-in.-wide specimens (Fig. 4(*a*) as compared to the slope for the 3-in. wide specimens (Fig. 4(*b*)). In summary, the limiting notch radius for H-11 tempered at 1000 F is ¼ mil for either 3- or 1-in.-wide specimens, but if larger radii are used, then the K_c values increase less rapidly with radius for the wider specimens. These conclusions on the interaction between width and radius are consistent with the edge-notch data of Table IV. The K_c values for 1-in.-wide edge-notch specimens varied from equality with, to much greater than, values obtained with central-fatigue-crack specimens. In contrast, 3-in.-wide edge-notch specimens gave K_c values that were in good agreement with those obtained from fatigue-cracked specimens.

Method of Notch Fabrication

Both electrical discharge machining and grinding were used to produce the notches of successive radii in the 1-in.-wide edge-notch data of Fig. 4(*a*). Within the limits of scatter there are no clear differences in K_c values for specimens ground or electrically slotted to the same radius. This result should not be generalized to include all possible notching methods nor to other materials having fundamentally different microstructures.

Comments on Ink Staining

In this investigation, ink staining was used to measure the slow crack extension. Ink stains were generally measured using a decimal scale graduated in 0.020 in.; however, the precision of this measurement is sometimes much finer than the accuracy with which ink stains measure slow crack extension. During the course of this investigation, and in other investigations at NASA and NRL since the publication of the first committee report (**1**), considerable experience has been gained with the ink-stain technique. There is no question that a considerable amount of experience is necessary in applying the ink and in deciding whether or not the resulting pattern truly represents the slow crack extension. If too much ink is used, splattering may occur during final fracture and render the pattern useless. On the other hand, if insufficient ink is available the measured values will be too short. It must be remembered that the forces of surface tension acting on the ink at the crack tip will always tend to throw some ink ahead of the slow crack boundary. This means that the ink stains generally terminate in an irregular manner and that even in the absence of any slow crack some stain would be observed. In this connection, it might be expected that higher capillary forces would occur as the slot space is decreased and therefore that specimens with narrow slots terminating in fatigue cracks would tend to throw more ink ahead of the slow crack boundary than specimens with relatively wide V notches.

In any event, both halves of the specimen must be carefully examined to make sure that each fracture surface has been wet by ink in the area to be measured. An example of the type of error that can result from incorrect ink stain interpretation is given by data obtained for 1.5-in.-wide central-fatigue-crack specimens of B120 VCA. Two sets of K_c data were computed from examination of these ink stains as shown in Table XII. The initial interpretation was fairly literal, with areas of ink being included which appeared on only one specimen half. The resulting mean K_c was 50,600 psi-$\sqrt{\text{in.}}$ More careful interpretation of the stains gave a value of 42,400 psi-$\sqrt{\text{in.}}$, which was previously reported in Table V and is in good agreement with that obtained using other specimen types.

TABLE XII.—INFLUENCE OF INK STAIN MEASUREMENT ON K_c VALUES FOR B120 VCA SPECIMENS WITH FATIGUE CENTER CRACK, 1.5-IN. NOMINAL WIDTH.

Specimen Number	a/a_0	σ_N/σ_{ys}	K_c, ksi $\sqrt{\text{in.}}$	Mean K_c, ksi $\sqrt{\text{in.}}$
CCLS4	1.902[a]	0.444	49.5	...
CCLS5	1.906[a]	0.452	50.1	...
CCLS9	2.000[a]	0.483	52.2	...
...	...	...	...	50.6
CCLS4	1.627[b]	0.355	42.2	...
CCLS5	1.653[b]	0.365	43.2	...
CCLS9	1.627[b]	0.351	41.8	...
...	...	...	...	42.4

[a] Literal interpretation of ink stains.
[b] Ink stain lengths corrected on basis of splatter.

Fortunately, the relative accuracy in defining the true slow crack length increases with the length of the crack, since any ink irregularity at the slow crack boundary will be a smaller percentage of the total crack length as the ink stain becomes longer. On the other hand, when the slow crack is very short, the ink stain is only a small percentage of the initial notch length, and errors in defining the boundary will, of course, have only a small effect on the measured K_c value. For example, the major conclusion from the H-11 data was that the maximum allowable machined notch radius is ¼ mil. This conclusion might be thought to depend on the accuracy of the measurements of ink stains. However, setting the slow crack length equal to the initial crack length for all the data of Fig. 4(*a*) and repeating the analysis of Fig. 4(*a*) resulted in a maximum allowable machined notch radius of 0.00026 in. Thus, the limiting radius of ¼ mil was not changed when the ink stain was discounted completely. The ink stains should not generally be ignored, however, because a large change will occur in K_c values of a material like B120 VCA if the initial rather than the slow crack length is used in the K_c computation.

Reproducibility of Fracture Toughness Values

Reproducibility of K_c values was examined for specimens of the same type tested under essentially uniform conditions. Sufficient data were available for statistical analyses in the case of several specimen types of both H-11 modified (first heat) and B120 VCA. These data have been summarized in Table XIII and represent specimens for which ink stain determinations were made at NASA by one person.

The analysis of these data will consider the following quantities: (1) the sample mean $\bar{X}$ of the observed K_c values, (2) the sample standard devia-

TABLE XIII.—VARIABILITY OF K_c DETERMINATIONS.
[Specimens notched and heat treated.]

H-11, 1000 F Temper				B120 VCA, Aged 72 hr at 900 F					
1.2, 1.3 in. wide shear center crack		1.0 in. wide tool cut edge notch		1.5 in. wide fatigue center crack		1.3 in. wide shear center crack		1.0 in. wide tool cut edge notch	
Heat treat batch	K_c, ksi $\sqrt{\text{in.}}$	Heat treat batch	K_c, ksi $\sqrt{\text{in.}}$	Heat treat batch	K_c, ksi $\sqrt{\text{in.}}$	Heat treat batch	K_c, ksi $\sqrt{\text{in.}}$	Heat treat batch	K_c, ksi $\sqrt{\text{in.}}$
b	29.8	a	54.8	d	42.2	d	32.1	d	36.7
b	30.3	a	55.3	d	43.2	d	30.8	d	33.0
b	29.4	a	61.4	d	41.8	d	33.0	d	35.1
c	33.3	a	47.9	e	49.4	e	34.0	e	37.8
c	32.8	b	47.3	e	43.1	e	36.6	e	34.1
c	35.9	c	54.4	e	46.8	e	35.1	e	32.9
c	33.8	c	58.7	e	49.6	e	35.3	e	33.6
c	34.3	c	58.9	e	46.8	e	33.4	e	36.1
		c	53.9			e	37.2	e	34.3
S..........	2.4		4.8		3.2		2.1		1.7
$\bar{X}$..........	32.5		54.7		45.4		34.2		34.8
$S/\bar{X}$........	0.07		0.09		0.07		0.06		0.05

tion, S, which is a measure of the spread or scatter of the data about the mean, and (3) the coefficient of variation defined as the ratio of the standard deviation to the mean, $S/\bar{X}$, which gives an indication of how the scatter is related to the absolute value of the mean. The necessary equations for computing these quantities are as follows:

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} X_i$$

and

$$S^2 = \frac{1}{n-1}\sum_{i=1}^{n} (X_i - \bar{X})^2$$

where X_i is a particular K_c value of n values in the sample.

The computed values for $\bar{X}$, S, and $S/\bar{X}$ are given in Table XIII. The assumption has been made that differences in heat-treated batches may be neglected as one of the many small random variations typically entering into K_c measurements. The coefficients of variation did not differ significantly among specimen types. Furthermore, these coefficients are within the range that might be expected for testing relatively brittle alloys. In this connection it is of interest to compare these results with those obtained by Driscoll (5) in a study of the reproducibility of room-temperature Charpy impact values. In his investigation, many replicate impact tests were made under closely controlled conditions on a selected heat of SAE 4340 steel heat treated to yield three different energy levels (13, 49, and 78 ft-lb). Results for the lower energy level should be most comparable to those reported in this paper. The impact results, in ft-lb, were:

	Machine Type 1	Machine Type 2
$\bar{X}$..........	12.7	12.8
$S/\bar{X}$.......	0.041	0.044

These values for $S/\bar{X}$ may be compared with those obtained in this investigation shown in Table XIII. It is not considered that the coefficients of variation for the K_c values are significantly larger than those obtained from the impact tests.

Conclusions

This investigation was confined to $\frac{1}{16}$-in. thick specimens that varied in width from 1 to 3 in. The results are therefore based on width-to-thickness ratios that varied from 16:1 to 48:1. The three alloys tested were widely different in their composition and metallurgical structure. For this reason, unless otherwise stated, the following conclusions should have wide applicability to various high-strength alloy types.

1. The previously stated (1) notch radius requirement of 0.001 in. maximum is too large for some alloys to give K_c values representative of actual cracks. In the case of H-11 modified (1000 F temper) the notch radius required is 0.00025 in.; however, this value will undoubtedly vary with the alloy. At the present time it is not possible to state accurately the required radius for any given material. Fatigue-crack specimens of 1- and 3-in. widths gave the same K_c values. This behavior was observed for materials that varied widely in their amount of slow crack growth. However, the tests were limited to moderately brittle conditions (ratios of net stress to yield strength in the range of 0.15 to 0.40).

2. In comparison with fatigue-crack specimens, 3-in.-wide edge-notch specimens with a 0.0005-in. maximum notch radius were found to give generally the same, but sometimes slightly smaller K_c values. The smaller values might be associated with bending stresses due to asymmetrical slow crack development in the edge-notch specimen.

3. Ink stain determinations of slow crack length require careful interpretation of the stain pattern. However, the reproducibility of fracture toughness values is comparable to that expected from V-notch Charpy impact tests on material of comparable toughness.

4. Specimens having shear-punched stress raisers were not suitable for absolute measurements of fracture toughness for one alloy. That is, for 70 per cent cold-worked AISI 301 tested in the transverse direction, this specimen type did not reveal the brittleness indicated by specimens with central fatigue cracks or sharp machined notches.

5. Tests on one alloy condition (H-11 modified, austenitized in argon, 1000 F temper) indicate that the same mean K_c values are obtained whether fatigue cracks or machined notches are introduced before or after heat treatment.

References

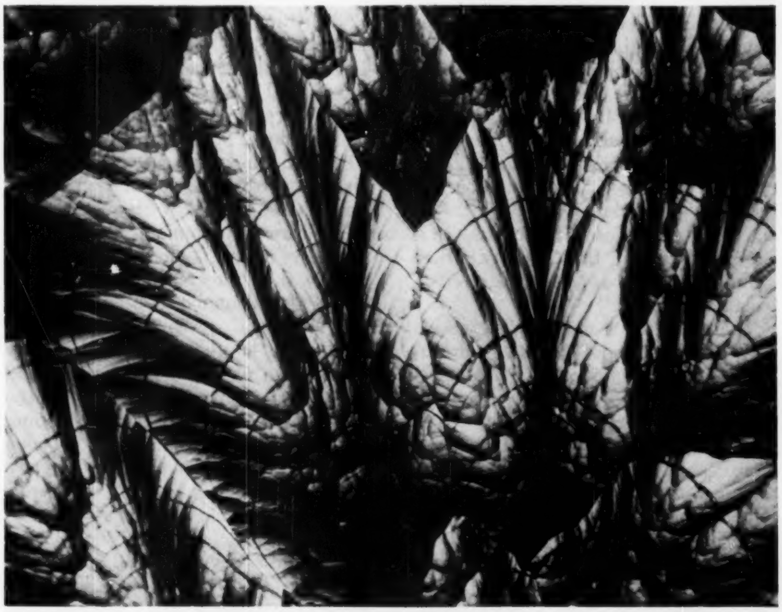
(1) "Fracture Testing of High Strength Sheet Materials: A Report of a Special ASTM Committee," ASTM Bulletin, No. 243, pp. 29–40, Jan., 1960; and No. 244, pp. 18–28, Feb., 1960.

(2) J. D. Morrison and J. R. Kattus, "Fracture Toughness Determinations with the Shear-Cracked Specimen," to be published in *Materials Research & Standards*," Vol. 1, No. 12 (Dec., 1961).

(3) J. L. Shannon, Jr., G. B. Espey, A. J. Repko, and W. F. Brown, Jr., "Effect of Carbon Content and Melting Practice on the Room Temperature Sharp Edge Notch Tensile Characteristics of H-11 Mod and 300M Sheet Steels," *Proceedings*, Am. Soc. Testing Mats., Vol. 60, pp. 761–795 (1960).

(4) G. R. Irwin and J. E. Srawley, "Progress in the Development of Crack Toughness Fracture Tests," presented at a meeting of the Deutscher Verband für Materialprüfung, Würzburg, March 16–17, 1961. To be published in *Materialprüfung.*

(5) D. E. Driscoll, "Reproductibility of Charpy Impact Test," Symposium on Impact Testing, *ASTM STP No. 176*, Am. Soc. Testing Mats., p. 70, (1955).



Vapor Phase Deposited Carbon

Specimen mounted under a vacuum and impregnated with polishing powder added to a cold-setting plastic. Polarized light. Magnification 200X, reduced for publication. Twelfth ASTM Photographic Exhibit. C. R. Lehmann and M. A. Miller, General Electric Co., Evendale, Ohio.

ASTM Abroad

The Society has come full circle—from the American branch of an international society to an American Society with international scope and influence.

Whether we like it or not, the world is getting smaller. Man can circumnavigate the earth in 90 minutes. Economic barriers are being lowered by common markets. American industry is feeling increasing pressure of foreign competition. And the rude hammering of a shoe in New York is heard in the remotest corner of the planet.

In the face of the Communist challenge, the response of the free world—painful, halting, agonizing though it may be—is a drawing together, militarily, politically, economically, in an effort to establish a common destiny. One imperative is to keep wide the arteries of international trade. For it is the flow through these arteries that nourishes the economies of all nations.

But trade between nations, as between men, presupposes a mutual understanding of exactly what is being bought and sold. T. A. Marshall, Jr., in describing a rejuvenated Pan American Standards Committee recently (*MR&S*, Oct., 1961, p. 808) said, "International trade . . . is a great dialogue for which nations must find a common language. That common language is industrial standards . . . . If the industrialization of Latin America is a major battle in the Cold War, then industrial standards are strategic weapons in our arsenal."

There is also a more selfish reason why we should take an interest in international standards. As Arnold Scott has said (ASTM Bulletin, Oct., 1960, p. 10), "If we are to share in international markets . . . we must become more standards-minded. Countries that are just now developing their resources and industry will most likely pattern their standards after international standards, and we shall be handicapped in the foreign market if we don't participate fully. We should, therefore, take a more active part in developing international standards to make sure that our point of view is well presented."

What about ASTM? This Society is unquestionably the voice of materials standards for the most powerful nation in the free world. Is that voice being heard outside our own shores? The fact that Mr. Marshall's words, quoted above, were part of a plea directed at U. S. industry for active support of Pan American standards is one clue to the answer. Other clues are the scope of ASTM participation in the work of the International Organization for Standardization (ISO); the extent of the contributions of foreign organizations and individuals to the work of the ASTM technical committees; the number of ventures undertaken cooperatively by ASTM and foreign groups; and the volume of sales, exchanges, and gifts of ASTM publications abroad.

ISO and IEC

The International Organization for Standardization (ISO) and its affiliated International Electrotechnical Commission (IEC) are the world clearinghouse for developing and promoting international standards. More than 40 nations are represented in ISO, the United States representation being through the American Standards Assn.

The European Common Market countries have already taken steps to accept jointly the recommendations of ISO and IEC. A number of other countries also apparently wish to have their standards developed internationally rather than on a unilateral basis, and they are focusing their efforts in the work of ISO rather than in developing their own national standards. In some areas the international discussions are having a distinct impact on standardization in the United States, and a number of ASTM committees (see box) are following these international discussions quite closely with the thought that ASTM standards and international recommendations should be in harmony. The list of ISO and IEC projects in which ASTM takes an active part continues to grow year by year.

International cooperation in developing standards also occurs on a less formal plane. Standards in draft form from foreign standardizing bodies are not infrequently submitted to ASTM technical committees for review and comment. For the most part, these come from English-speaking countries, but a growing number come from Latin America. Both parties benefit from this exchange of views on standards in the process of development.

Help from Abroad in ASTM

International cooperation is a two-way street. While ASTM is active in the cause of international standards, it can also be shown that foreign organizations and individuals are contributing on a large scale to the work of ASTM.

Nearly 15 per cent of the Society membership is from abroad. These are distributed all over the globe—from Iceland to New Zealand, from Okinawa to the Congo. In addition to these, there are nearly 200 non-Society members who hold memberships on the various technical committees.

Also represented on ASTM technical committees are more than 20 foreign trade associations, governmental departments, and research institutes and standardizing bodies. ASTM provides a special membership privilege for standardizing bodies in foreign lands which permits them to receive the complete Book of Standards upon payment of the dues for individual membership. Many standardizing bodies, particularly in South America, are taking advantage of this.

ASTM Headquarters frequently plays host to individuals and study groups from other lands, many of which are sponsored by the International Cooperation Administration. A recent check of the guest register in the lobby at 1916 Race St. revealed that, in the past few years, most of these groups had come from Japan, Great Britain, France, Italy, and Germany, but that most of the countries of the world were listed

there, and, in fact, the only major land area not represented was Antarctica.

ASTM publications are also enriched by contributions from abroad. During a recent five-year period, the Society published 89 papers from 123 foreign authors located in 21 different countries, including Canada. On the opposite side of this coin are the bibliographies and abstracts published by ASTM in the fields of fatigue, electrical contacts, spectrochemical analysis, metal cleaning, and analysis of synthetic detergents. In each of these an effort is made to survey and compile pertinent information from the world literature.

Joint Ventures

This is probably the most difficult area to describe, since activity is so widespread. In some cases the Society as a whole becomes cosponsor of an international event; at other times it may be a technical committee, or perhaps just an interested group within a committee. At another level, there may be joint sponsorship of a publication. There are also the numerous arrangements for promoting information exchange internationally. Some of the areas in which these joint ventures have taken or are taking place are:

Metals

The ASTM-ASME Joint Committee on Effect of Temperature on the Properties of Metals will cosponsor, with ASME and the Institute of Mechanical Engineers, a Joint International Conference on Creep in New York in August, 1963.

ASTM is a cooperating society in the publication of *Acta Metallurgica*, an international journal for the science of metals.

Through Committee E-3 on Chemical Analysis of Metals, the Society has arrangements for information exchange with the British Iron and Steel Inst. and with the Canadian Standards Assn.

Committee B-3 on Corrosion of Nonferrous Metals and Alloys is cooperating with the National Research Council of Canada in developing instruments for compiling atmospheric corrosion data. This program will eventually embrace corrosion sites in England, the Philippines, Canada, the United States, and the Panama Canal Zone.

Committee A-1 on Steel recently undertook to handle United States participation in the International Deep-Drawing Research Group.

Rubber and Plastics

In 1958 ASTM sponsored an International Symposium on Plastics Testing and Standardization, in behalf of ISO 61 on Plastics. Eighteen of the 24 papers presented at the symposium, held in Philadelphia, were from countries other than the United States.

In 1959, ASTM cosponsored, with The American Society of Mechanical Engineers and the American Chemical Society, an International Conference on Rubber, in Washington, D. C.

Nuclear Congress

ASTM is one of many cosponsors of the biennial Nuclear Congress. At the 1964 congress ASTM will sponsor, with the International Union of Testing and Research Laboratories for Materials and Construction (RILEM), a symposium on application of Atomic Physics for Tests of Materials.

Soils

In 1958, Committee D-18 on Soils for Engineering Purposes and the Mexican Society of Soil Mechanics sponsored jointly a symposium in Mexico City. The 14 papers from the meeting were published in both Spanish and English.

Cellulose

Committee D-23 on Cellulose and Cellulose Derivatives has actively aided the work of the International Committee on Cellulose Analysis (ICCA). Since its organization in 1953, one of the most significant activities of this group has been to establish and stockpile eight standard samples of cellulose that cover the range of commercial interest. These samples permit anyone in the world to study new test methods on cellulose and to compare results with other methods on the same material. Data in this field are being correlated by Committee D-23 jointly with the American Chemical Society and TAPPI.

Petroleum

ASTM and the Institute of Petroleum (London) are pre-eminent for the petroleum standards published jointly by these societies. The ASTM-IP Petroleum Tables are used throughout the world. Committee D-2 on Petroleum Products and Lubricants also maintains contact with the Bureau de Normalization due Petrole (Paris) and the FAM Committee of the Deutsche Normenausschuss (Hamburg). These contacts often result in the adoption of ASTM petroleum methods *in toto* or in modified form in British, French, and German standards. They also benefit Committee D-2 by bringing into its counsels the experience of groups from other lands.

Passivity

ASTM will cosponsor the Second International Symposium on Passivity, to be held in September, 1962, in Canada. Other sponsors are the Electrochemical Society, the Faraday Society, and the Deutsche Bunsen Gesellschaft, with financial support from the National Research Council of Canada.

Participation by ASTM in ISO and IEC

Technical Committee	Material	ASTM Participant
ISO 6	Paper	D-6 on Paper and Paper Products
ISO 17	Steel	A-1 on Steel
ISO 24	Sieves	ASA Project Z23 (cosponsors: ASTM and the National Bureau of Standards)
ISO 25	Cast Iron	A-3 on Cast Iron (Advisory Committee)
ISO 26	Copper	B-5 on Copper and Copper Alloys
ISO 27	Solid Mineral Fuels	D-5 on Coal and Coke (Sub. XXVII)
ISO 28	Petroleum	ASA Project . Z11 (sponsored by ASTM)
ISO 33	Refractories	C-8 on Refractories
ISO 35	Raw Materials for Paints, Varnishes, and Similar Products	D-1 on Paint, Varnish, Lacquer, and Related Products
ISO 38	Textiles	ASA Project L23 (sponsors: ASTM and the American Association of Textile Chemists and Colorists)
ISO 45	Rubber	D-11 on Rubber and Rubber-like Materials
ISO 47	Chemistry	E-15 on Industrial Chemicals
ISO 50	Lac	D-1 Subcommittee XIII on Shellac
ISO 56	Mica	Sub. IX on Mica Products of D-9 on Electrical Insulating Materials
ISO 61	Plastics	D-20 on Plastics
ISO 66	Viscosity	Sub. 9 on Rheological Properties of E-1 on Methods of Testing
ISO 69	Statistical Treatment of Series of Observations	Special ASTM group
ISO 74	Hydraulic Binders	C-1 on Cement
ISO 77	Asbestos Cement Products	C-17 on Asbestos-Cement Products
ISO 78	Industrial Aromatic Hydrocarbons	D-16 on Industrial Aromatic Hydrocarbons and Related Materials
ISO 79	Light Metals and Alloys	B-7 on Light Metals and Alloys
ISO 91	Surface Active Agents	D-12 on Soaps and Other Detergents
IEC 7	Aluminum	ASA Project C7 (sponsor ASTM)
IEC 10	Insulating Oils	D-27 on Electrical Insulating Liquids and Gases
IEC 14A	Magnetic Steel	A-6 on Magnetic Properties
IEC 15	Electrical Insulating Materials	D-9 on Electrical Insulating Materials


los Standard para la Determinación
equeñas Cantidades de Cobre y
ganeso en Materias Textiles (1)
Designación ASTM: D 377-54
噴霧試験装置
フレーテスター
株式会社 東洋精機製作所
ASTM STANDARDS ON GLASS AND PRODUCTS
ASTM STANDARDS ON SOAPS AND OTHER DETERGENTS
Norme dell'ASTM sui conduttori
Publications de l'American Society Testing Materials
純国産の 塩水噴霧試験装置
U.S. HQ NORTHERN AIR MATERIAL AREA PACIFIC.
CATALOGING AND STANDARDIZATION DIVISION.
7CAD-PA-81984
FEDERAL STANDARD. ASTM. JIS. M
Über die Analyse von Kohlenwasserstoffen
5. Mitteilung: Über die Analyse und Bewertung von Rohölen
Teil II: Versuchsergebnisse
TO COUNTER WEIGHTS
WATER SEAL
SUSPENDED COVER
WINDOW
LONGITUDINAL SECTION THROUGH SALT SPRAY BOX
(ASTM B-117)
Norme ASTM per materiali di tubazione
Unificazioni ASTM per i metalli leggeri

ASTM Abroad

Mechanics

ASTM is a member of the U. S. National Committee on Theoretical and Applied Mechanics. This joint committee represents the United States in the International Union on T&AM. One of the activities of this Union is the sponsoring of the quadrennial International Congress on Applied Mechanics.

Fatigue

Committee E-9 on Fatigue corresponds regularly with fatigue experts in Sweden, Australia, France, Germany, England, and Japan who are corresponding members of the committee. In this way the committee keeps abreast of what is being done abroad and also keeps those abroad informed on what is going on in the United States.

ASTM Publications Abroad

Sales

Sales of ASTM publications abroad are now running at the rate of about 10,000 orders per year, for a total volume of nearly $250,000. In addition to this, nearly $60,000 worth of X-ray powder data cards and index books go abroad every year. These cards are the result of a joint effort among ASTM, the American Crystallographic Assn., the British Institute of Physics, and the National Association of Corrosion Engineers. The data on the cards are gathered from many countries of the world.

Foreign sales of publications occasionally create some excitement for our order department. On a shipment to Europe some time ago of Cotton Yarn Appearance Boards, the photographs, when opened for customs inspection, were slashed with a knife and ruined. We sent a replacement shipment which, while being unloaded at the dock, dropped into the sea. A third shipment arrived safely. Since then, this customer has always specified air shipment.

On one order for petroleum standards, sent to the Far East just before the Japanese breakthrough in 1941, we received many urgent letters from the home office in Europe asking us to express an opinion as to whether the books had reached their destination ahead of the Japanese. Just after the end of the war, a large shipment of books was returned to us, which had evidently been held in a warehouse somewhere in the Far East all during the war. They had mildewed and disintegrated to the point where they were worthless, even as scrap paper.

One shipment of the Book of Standards, worth several thousand dollars, was sunk in a collision in a dense fog in New York Harbor. More than one shipment has been returned to us charred and waterlogged after a fire at sea.

Exchanges

Some 20 foreign organizations and schools receive ASTM publications on a free or exchange basis. In addition to these, *MR&S* is exchanged with about 40 foreign periodicals and sent free to more than 100 recipients abroad. The Society also cooperates whenever possible with the Engineers and Scientists Committee of the People-to-People Program. This organization is operated by retired executives who donate their time to sending books overseas.

This year, ASTM is participating in the Trade Missions Program of the Bureau of Foreign Commerce, U. S. Department of Commerce, by contributing copies of *MR&S* and the Book of Standards. The Bureau adds these publications to the commercial libraries it sends to foreign countries, which are then used by Trade Mission members and our embassies and consular posts to bring to the attention of foreign businessmen the services and products available from U. S. firms.

Translations

A number of ASTM standards have been translated into foreign languages, principally Spanish, and plans are afoot for more. Some years ago the U. S. Department of Commerce translated into Spanish and Portuguese a group of standards for metals. In 1948 the Republic of Argentina translated into Spanish and published the compilation of standards on petroleum. In 1941 ASTM published a special compilation of standards on refractories which had been translated into Spanish under the auspices of the American Refractories Inst. Parts of the ASTM-IP Petroleum Measurement Tables have been translated into Spanish for use in Venezuela.

Last year we gave permission to the United Nations to translate into French and Spanish and publish a group of soils standards in a proposed manual on stabilized soil construction for housing. This project is being supported by the UN Technical Assistance Program.

A proposal for a rather extensive translation of selected ASTM standards, with the help of the International Cooperation Administration, is now under consideration in the Department of Commerce.

With Influence: Responsibility

This brief account of the major aspects of ASTM on the international scene by no means exhausts the subject. A complete listing, in fact, would impose undue hardship on the researcher and on the reader alike. It does serve, however, to illustrate the fact that this Society, which began in 1898 as the American Section of the International Association for Testing Materials, has become truly international in scope and influence.

International influence, however, brings international responsibilities. If the members of this great and unique Society wish to see that influence grow, they must be prepared to shoulder that responsibility. If the admonitions of Messrs. Marshall and Scott, cited earlier, are taken at their face value, we must be prepared to believe that the economic well-being, perhaps the chances for survival, of our nation will be improved in proportion to our efforts in the area of international standardization.

Literature Searches Now Available from OTS

THE OFFICE of Technical Services, in cooperation with the Science and Technology Division of The Library of Congress, has launched a new service, which offers "tailor-made" bibliographies of material in two major Government literature resources.

Under the new plan, OTS will compile lists of relevant publications from among its holdings of Government research reports, unclassified and declassified AEC reports, technical translations, and Government-owned patents. At the same time, the Science and Technology Division of The Library of Congress will provide citations, with or without abstracts, to publications in the Library's science and technology collections.

The domestic report collections of OTS constitute a rich and growing concentration of information deriving from Government-sponsored research and development. In addition, through the translation collection, access is provided to valuable information, in English, resulting from foreign science and technology. The science collections of The Library of Congress, which are preeminent in many disciplines, cover broadly the world output of literature in all major fields of science and technology.

Two types of literature service are offered. The first is a "current awareness" bibliography service, which enables the subscriber to keep abreast of new developments in his field of interest on a periodic basis. The second is a retrospective bibliography service, which results in a list of the literature available at the time the request is made.

Details are available from any Department of Commerce Field Office or from: Technical Information Div., OTS, Washington 25, D. C.

Society Affairs

Program Set for Electroforming Symposium

Will cover applications, uses, and properties of electroformed metals

THE FIRST COMPREHENSIVE coverage of a new and growing industry, with great potential for the future, will be offered by recognized authorities in the field at the Symposium on Electroforming to be held Feb. 6–7, 1962, during ASTM Committee Week in Dallas, Tex. This symposium will be of great value to both the materials engineer and the designer looking for a new means of filling the design-technology gap.

Electroforming is the science of creating or reproducing objects by electrodeposition. This method of fabrication is already being used in many applications for producing articles of simple or complex shape to extremely close dimensional tolerances—from tiny orifices for hydraulic control devices to wind tunnel venturis weighing several thousand pounds.

The two-day symposium will include papers and discussions on the solutions used, the techniques employed, and the use of the science in the production of many different types of objects. This is a subject of growing national interest, and the papers will, for the most part, present new and previously unpublished material in the field.

Every aspect of the subject will be covered, including the design, manufacture, use, and choice of materials for patterns; rack design, anode distribution, and methods for local control of current density in the bath; plating baths, effect of bath contaminants on properties of the product, and control of contaminants; physical properties of electroformed hardware; types of applications where electroforming is use-

Following Committee Week:

Tour to Mexico City and Acapulco

FLUSHED WITH the success of the post-Annual Meeting Conference in Bermuda last June, Headquarters has arranged for a similar week-long affair in Mexico following Committee Week in Dallas. The tour dates: February 9–17, 1962. The cost: only $175 per person for double accommodations. The itinerary:

Friday, Feb. 9, depart Dallas on American Airlines Flight 783 at 12:50 p.m., arrive Mexico City at 5:40 p.m. Only 37 tourist seats available on first-come-first-served basis, remainder are first-class seats at slightly higher fare. Limousine to Hilton Continental Hotel in Mexico City. First evening cocktail reception. Only one lunch is included in Mexico City portion of tour to leave you free to choose among the many wonderful dining facilities.

Saturday morning, limousine tour of Mexico City. Afternoon tour to University of Mexico City with guided lecture through School of Engineering, Art, and Design. Sunday, tour to Benito Juarez housing project, visit to

COLORFUL FLOATING GARDENS OF XOCHIMILCO

ful; and experience with electroforming in many different types of industry from phonograph records to plasma arc torches. The detailed program follows:

Session A—Introduction, Solutions, and Deposit Properties

9:00 a.m., Tuesday, Feb. 6, E. B. Saubestre, chairman

Introduction to Electroforming—A. K. Graham, Graham, Savage and Associates, Inc.

Modern Electroforming Solutions and Their Applications—M. B. Diggin, Hanson-Van Winkle-Munning Co.

Physical and Mechanical Properties of Electroformed Nickel at Elevated and Subzero Temperatures—C. H. Sample and B. B. Knapp, International Nickel Co., Inc.

Physical and Mechanical Properties of Electroformed Copper—W. H. Safranek, Battelle Memorial Inst.

Session B—Engineering, Automotive, Sound, and Miscellaneous Parts Manufacture

2:00 p.m., Tuesday, Feb. 6, A. H. DuRose, chairman

Practical Methods in the Use of Electroforming Masters, Mandrels, and Matrices—F. R. Bottomley, Gar Precision Parts, Inc.

The Application of Electroforming to the Manufacture of Disc Records—A. M. Max, Radio Corporation of America

Electroforming Plastic Molds for the Automotive Industry—P. J. Ritzenthaler, Plating Engineering Co.

Manufacture of Typing Wheel Electrotypes and Other Electroformed Piece Parts—K. W. Franks, Teletype Corp.

Session C—Aviation and Aerospace Applications

9:00 a.m., Wednesday, Feb. 7, R. B. Saltonstall, chairman

Electroforming Hardware for Aerospace Vehicles—D. L. Allie and J. C. Ladd, General Dynamics Corp.

Alloy Electroforming for High-Temperature Aerospace Applications—M. E. Browning, General Dynamics Corp.

Electroforming Supersonic Pitot-Static Tubes—F. K. Savage, Savage-Rowe Plating Co., Inc.

Electroforming of Venturi-Type Liners for Wind Tunnels and Other Applications—P. C. Silverstone, Electroforms, Inc.

Session D—Open Forum Discussion

2:00 p.m., Wednesday, Feb. 7, A. D. Squitero, chairman

This session will include a motion picture on the manufacture of electrotype printing plates.

Letter Ballot Returns

THE SOCIETY letter ballot dated September 1, 1961, contained two items affecting the By-laws and 305 items affecting standards. A canvass of the returns indicates that all items are approved. The changed sections of the By-laws should now read as follows:

Article IV. Duties of Officers.

Section 5 (new section).—The Board of Directors may, in its discretion, appoint a member or members, or other person or persons, to represent it at meetings of societies of kindred aim or at public functions. Such delegates may be designated as "Honorary Vice-president," and their duties shall terminate with the occasion for which they are appointed.

Renumber old Section 5 as Section 6.

Article VIII. Dues.

Section 5.—Any person elected after six months of any fiscal year shall have expired may pay only one-half of the amount of dues for that fiscal year.

Section 6 (new Section).—At its discretion, the Board of Directors may confer life membership upon any person who is an individual member.

Philadelphia Pays Tribute To President Clair

A Distinguished Citizen Tribute from the City of Philadelphia was awarded to ASTM President Miles N. Clair on Sept. 18 by Philadelphia's Mayor Richardson Dilworth at a special ceremony held in the Mayor's Reception Room at Philadelphia City Hall. The tribute honored Dr. Clair for his achievements in the world of engineering and for his many contributions to his community. The text of the tribute:

Mayor Dilworth (*left*) presents tribute to Dr. Clair

Philadelphia's reputation as a seat of scientific and technical endeavor is worldwide. Any roster of the distinguished men and women associated with its institutions must include Dr. Miles N. Clair, president of The Thompson & Lichtner Co., Inc., and new president of the American Society for Testing Materials.

Dr. Clair spent his boyhood in Pennsylvania, and was graduated from West Philadelphia High School. He received his engineering education at Drexel Institute of Technology, taught there for several years, and returned in 1951 as one of 60 honored alumni. In 1960 the school conferred on him its Honorary Doctor of Engineering Degree. Other recognitions have come from many leading engineering organizations and philanthropic and civic agencies in which he is active.

More than any other engineer, Dr. Clair has been credited with developing the use of pre-cast and pre-mixed concrete. His company pioneered in developing ready-mixed concrete procedures, permitting trucks to supply concrete to projects in large quantities. Under his direction, his company originated many pre-casting methods. Bridges, airports, military bases, and other major facilities built by his firm are located both in this country and abroad. Dr. Clair's personal research, writings, and consultation service have contributed greatly to the advancement of concrete construction.

Honor accorded Dr. Clair stems from the bedrock of great achievement, in turn based on his outstanding personal qualities of imagination, thoroughness, and boundless energy. In view of his prolific creativity and his service in furthering human betterment, bringing honor to himself and this City's institutions, the City of Philadelphia elects to award this tribute.

On receipt of the award, Dr. Clair, in turn, paid tribute to the Society. "In accepting this citation," he said, "I do so conscious not only of the honor you do me but of the recognition it gives to the profession of civil engineering, to which I belong, to the American Society for Testing and Materials, of which I am president, and to the schools of Philadelphia, of which I am a graduate.

"The civil engineering profession has had a large part in the development of this country to the position of the greatest in the world; and its work is evidenced by the highways, harbors, bridges, buildings, and other structures that surround us and contribute to our health, welfare, and happiness. The activities of the American Society for Testing and Materials, which was organized in Philadelphia on June 16, 1898, and which has maintained its headquarters here ever since, are vitally important to the industrial, technological, and scientific progress of our country. This organization is unique in the world in that it develops by the voluntary cooperative action of scientists and technical men representing producers, consumers, government agencies, and universities standards for materials and for the testing of materials. These standards provide a basis for quality specifications to meet the desired use and a method of testing to check whether the specifications are met. Resulting economy of production of standard quality materials and the freedom of competition thus made possible are two of the major factors in the high productivity and low cost of American industry.

"My sincerest thanks to you, Mayor Dilworth, and to the City of Philadelphia for this great honor."

Offers of Papers for 1962

The Administrative Committee on Papers and Publications will meet early in February to consider the papers to be published by the Society in 1962 and to develop the programs for the Annual Meeting (New York, June 24–29) and the Fourth Pacific Area National Meeting (Los Angeles, Sept. 30–Oct. 5).

All those who wish to offer papers for presentation at either or both of these meetings and publication by the Society should send these offers to Headquarters *not later than January 10, 1962.*

All offers should be accompanied by a summary that makes clear the intended scope of the paper and indicates features of the work that will, in the author's opinion, justify its publication and inclusion on the program.

Forms for supplying this information are available from ASTM Headquarters.

ASTM Board of Directors Highlights of September Meeting

THE BOARD MET at Headquarters in Philadelphia, Sept. 19, 1961. Present were: President M. N. Clair; Vice-presidents R. W. Seniff and A. C. Webber; Past-presidents K. B. Woods, F. L. LaQue, and A. A. Bates; Directors A. R. Belyea, A. M. Bounds, L. V. Cooper, A. G. H. Dietz, B. W. Gonser, J. C. Harris, J. J. Kanter, C. L. Kent, W. A. Kirklin, G. M. Kline, H. C. Miller, C. F. Nixon, J. B. Rather, Jr., H. D. Wilde, W. R. Willets, and I. V. Williams. Staff members present: T. A. Marshall, Jr., executive secretary; R. E. Hess, associate executive secretary; R. J. Painter, consultant to the executive secretary; and F. F. Van Atta, treasurer. Other Staff members were in attendance as the need for their presence arose.

Reappointments

The Board made the following reappointments: T. A. Marshall, Jr., as executive secretary; R. E. Hess as associate executive secretary; F. F. Van Atta as treasurer; and Miss Dorothy P. Douty as assistant treasurer.

Pan American Standards Committee

The Executive Committee approved a contribution of $250 toward the $5000 dues which the American Standards Assn. pays to the Pan American Standards Committee.

Membership on Administrative Committees

Effective January, 1962, persons appointed to Administrative Committees must be either personal members of the Society or official representatives of company or sustaining memberships.

Dues Exemptions

Exemption from further payment of dues will be offered to those who have been personal members for 35 years or those who have been personal members for 25 years and whose total of age and years of personal membership equals 95 years. Such dues-exempt members will continue to receive *MR&S* but not the complimentary Part of the Book of Standards.

1962 Budget

The Board approved a budget for 1962 of nearly $2 million. The 1961 budget was about $1.5 million.

Headquarters Expansion

The Board approved the recommendation of the Headquarters Expansion Committee that a new and expanded Headquarters building be erected on the present Race-Cherry St. site.

Nominating Committee

The following were appointed to the Nominating Committee: Members: W. H. Mayo, L. A. O'Leary, G. H. Harnden, H. M. Hancock, C. F. Lewis, and F. G. Tatnall. Alternates (respectively): H. R. Boatman, P. V. Garin, S. A. Standing, H. C. Cross, Cecil Shilstone, and J. A. Truitt.

DMS By-laws

The By-laws of the Division of Materials Sciences were approved. Division Chairman K. B. Woods announced that a one-day session on stress - strain - time - temperature relations in materials will be sponsored by the Division at the Society's 1962 Annual Meeting in New York.

West Coast Meeting

Appointments of the members of the General Committee on Arrangements for the Fourth Pacific Area National Meeting (Los Angeles, Sept. 30–Oct. 5, 1962) were confirmed. Officers of this committee are: chairman, Ernst Maag, California State Department of Public Works, Los Angeles; vice-chairman, W. T. Wright, Kistner, Wright & Wright, Los Angeles; vice-chairman, P. E. McCoy, American Bitumuls and Asphalt Co., San Francisco; Secretary, Carl Hurty, Los Angeles Department of Water and Power; treasurer, C. T. Test, Riverside Cement Co., Los Angeles.

Districts

On recommendation of both Districts concerned, the Board voted to transfer the Eastern Shore of Virginia from the Philadelphia to the Washington District.

Awards

Establishment of an "ASTM Award to Executives" was approved. Purpose: "To honor an executive who, through his outstanding interest and support, has furthered the accomplishments of ASTM." This award will be made not more often than once a year.

The Board also approved the establishment of an "Adhesives Award." Its purpose: "To recognize outstanding work in the science of adhesion and/or the technology of adhesives. This work may consist of a single achievement or a series of achievements over a period of time by one or more investigators." This award may be made yearly, with the recipient selected by committee D-14 on Adhesives. The certificate and honorarium will be furnished through the generosity of *Adhesives Age* magazine.

Technical Activities

Synthetic Polymer Roofing Solutions.—The scope and membership of Committee D-8 on Bituminous Materials for Roofing, Waterproofing, and Related Building or Industrial Uses will be enlarged so that it can undertake the development of standards for synthetic polymer roofing solutions. Committee D-11 on Rubber and Rubber-like Materials will also participate in this work.

Nomenclature and Definitions.—Committee E-8 on Nomenclature and Definitions will be reorganized to enable it to function more effectively.

Numerical Data.—The President was authorized to appoint a Special Committee on Numerical Data with the following scope:

1. Encourage accumulation, evaluation, and dissemination of data on pure substances and commercially important materials.
2. Improve communications among ASTM groups and others working in this general area.
3. Encourage use of standard methods for presentation of data.

D-20 Secretariat.—The Board approved the request of Committee D-20 on Plastics for Staff secretarial service as an interim measure, pending completion of the over-all study of this subject by the Long Range Planning Committee.

ASTM MEETINGS

Date	Group	Place
Dec. 4–5	Committee B-6 on Die-Cast Metals and Alloys	Washington, D. C. (Mayflower)
Dec. 6 (tentative)	New York District	New York, N. Y.
Dec. 6–7	Committee B-7 on Light Metals and Alloys, Cast and Wrought	Washington, D. C. (Willard)
Dec. 7	Committee D-21 on Wax Polishes and Related Materials	New York, N. Y. (Hotel Roosevelt)
	1962	
Jan. 14–17	Committee D-19 on Industrial Water	West Palm Beach, Fla. (Town House)
Jan. 18–19	Committee E-18 on Sensory Evaluation of Materials and Products	West Palm Beach, Fla. (Town House)
Jan. 21–24	Committee A-1 on Steel	Atlanta, Ga. (Atlanta Biltmore)
Jan. 21–26	Committee D-2 on Petroleum Products and Lubricants	St. Louis, Mo. (Chase-Park Plaza)
Jan. 22–24	Committee D-5 on Coal and Coke	Pittsburgh, Pa. (Webster Hall)
Jan. 24	Committee D-23 on Cellulose and Cellulose Derivatives	New York, N. Y. (Commodore)
Jan. 25–26	Committee D-6 on Paper and Paper Products	New York, N. Y. (ASA Headquarters)
Jan. 29–30	Committee E-15 on Analysis and Testing of Industrial Chemicals	Philadelphia, Pa. (Benjamin Franklin)
Jan. 29–31	Committee D-1 on Paint, Varnish, Lacquer, and Related Products	St. Louis, Mo. (Statler)
Feb. 5–9	**Committee Week**	**Dallas, Tex. (Statler-Hilton and Sheraton-Dallas)**
June 24–29	**Annual Meeting**	**New York, N. Y. (Statler)**
Sept. 30–Oct. 5	**Pacific Area Meeting**	**Los Angeles, Calif. (Statler-Hilton)**
	1963	
Feb. 4–8	**Committee Week**	**Montreal, P. Q. (Queen Elizabeth)**
June 23–28	**Annual Meeting**	**Atlantic City, N. J. (Chalfonte-Haddon Hall)**

International Deep - Drawing Research Group.—United States participation in this group will be handled by Committee A-1 on Steel.

Technical Assistant for C-1.—J. R. Dise was reappointed technical assistant to Committee C-1 on Cement for an additional year.

ECPD

The Executive Secretary was directed to explore with the Engineer's Council for Professional Development how ASTM might best cooperate with ECPD, particularly in the area of accrediting engineering curricula in the materials field.

Change of Society's Name

It was reported that the Society's name had been officially changed to the American Society for Testing and Materials with the signing of a court decree on Sept. 18, 1961, amending the Society's Charter. Approval to request such amendment was granted by vote of the membership at a business meeting held June 27, 1961, during the Annual Meeting.

International Symposium Postponed

It was announced that the Joint International Symposium on Applications of Atomic Physics for Tests of Materials, originally scheduled for 1962, will be postponed until the time of the next Nuclear Congress, in 1964.

Appointments to Administrative and Special Committees

Administrative Committee on District Activities.—H. F. Beeghly, E. J. Dunn, Jr., W. J. Klayer, C. S. Macnair, F. J. Mardulier, H. E. Montgomery, Cedric Willson.

Administrative Committee on Papers and Publications.—Thomas Hazen, R. C. Milenz, E. C. Schuman, F. B. Stulen.

Administrative Committee on Research.—W. O. Baker, J. H. Jackson, E. I. Shobert, B. L. Wilson.

Administrative Committee on Simulated Service Testing.—J. W. Goff, W. J. Hamburger, A. F. Jones, E. F. Seaman, H. H. Zurburg.

Administrative Committee on Standards.—G. H. Harnden, L. J. Jacobi, I. V. Williams.

Richard L. Templin Award Committee.—L. J. Markwardt.

Sam Tour Award Committee.—Jerome Strauss.

Edgar Marburg Lecture Committee.—A. A. Bates, J. C. Harris, C. A. Carpenter, R. F. Legget, E. I. Shobert.

H. W. Gillett Lecture Committee.—A. A. Bates, C. A. Carpenter, C. A. Lorig.

Charles B. Dudley Medal Committee.—Samuel Epstein, P. V. Faragher, P. V. Garin, J. V. Emmons.

Award of Merit Committee.—A. A. Bates, F. C. Burk, E. R. Thomas.

Committee on Fellowships and Grants-in-Aid.—K. B. Woods.

Advisory Committee on Corrosion.—C. P. Larrabee.

Committee E-1 on Methods of Testing.—R. P. Lathrop, W. J. McCoy, E. T. Scafe, Howard Tangenberg, R. D. Thompson.

Other Appointments

Society representative to the International Symposium on Microchemical Techniques, Aug. 13–18, 1961, at The Pennsylvania State University.—A. Steyermark.

ASA Sectional Committee on Radiation Protection (N7).—J. B. Trice.

ASA Sectional Committee on Hydraulic Cements (Al).—T. B. Kennedy.

Subcommittee on Plastic Pipe Fittings of ASA Sectional Committee on Pipe Flanges and Fittings (B16).—J. Jaglon.

ASA Sectional Committee on Pipe Flanges and Fittings (B16).—K. W. Haupt.

Suggested committee of the American Public Health Assn. to determine methods of testing that should be included in a manual on air pollution.—Morris Katz and M. D. Thomas.

ASTM Standards at Work

United Engineering Center

More than 44 ASTM standards were cited in the construction specifications for the United Engineering Center, the 20-story glass and stainless steel building in New York, which recently became the new home for 18 major engineering societies and the Engineers Joint Council.

Containing about 250,000 sq ft of floor space, the Center is a welded structural steel frame with exterior curtain wall construction. All window walls are faced with stainless steel, with fixed plate glass windows and blue-tinted glass spandrels. Perimeter columns of the tower are exposed on the outside and sheathed in stainless steel. The entrance lobby is marble-walled, and terrazzo-floored corridors lead to meeting, dining, and semipublic rooms and to four automatic push-button passenger elevators.

ASTM standards used were:

Foundations

Concrete aggregates, portland cement, reinforcing bars, and strength of concrete: A 15, C 33, C 39, C 87, C 131, C 150

Structural Steel

Structural steel, welding electrodes: A 7, A 141, A 233

Concrete Arches

Steel pipe, wire fabric for reinforcing, concrete aggregates: A 185, A 315, C 330

Masonry

Lime, brick, concrete masonry units: C 5, C 27, C 62, C 90, C 129, C 207

Waterproofing, dampproofing, caulking, roofing, coal tar, asphalt: D 227, D 447, D 450

Plastering, wallboard, gypsum, Keene's cement, lime: C 5, C 22, C 28, C 35, C 79, C 206

Tile work and terrazzo, masonry cement: C 91, and general references to ASTM standards covering sand and cement.

Paint

Paint, paint products, protective coatings: A 123, B 6, D 13, D 79, D 81, D 234, D 260, D 360, D 476, D 477, D 600, D 962, D 1187

The building was constructed at a cost of about $12 million, most of the money coming from contributions of many thousands of individual engineers, augmented by substantial gifts from industry. Funds were raised for the building, and its over-all planning and construction supervised, by the United Engineering Trustees, Inc. The architects were the firm of Shreve, Lamb & Harmon Associates, of New York, whose notable achievements include the Empire State Building. Turner Construction Co. was the general contractor.

Though there may be no revolutionary concept in this edifice, it is a great symbol of a proud profession. When the time came for the engineers to create their own headquarters, the improvements developed for others were incorporated in the Center. In other words, the profession's best service to itself was to do what it has been doing for others all along.

Electron Microscopy Congress Set for Next Year

The Electron Microscope Society of America will be the host for the International Federation of Electron Microscope Societies at the Fifth International Congress for Electron Microscopy, to be held in Philadelphia, Pa., Aug. 29–Sept. 5, 1962. The last Congress was held in Berlin in 1958.

The committee hopes to have available for each active member at the Congress a bound copy of the scientific papers at the time of registration. Address inquiries to the Congress, 7701 Burholme Ave., Philadelphia 11, Pa.

ASA Survey Shows Increasing Reliance on Standards

INCREASED RELIANCE upon standards and standardization programs to offset the cost-profit squeeze was reported by 67 companies responding to a recent American Standards Assn. questionnaire. Without exception, all firms stated that their standards activities had contributed substantially to reducing costs.

Specific savings information was made available by 15 of the companies. Reported savings ranged from 1 to 20 per cent of gross income. Other companies reported a range of \$3 to \$5 gained for each \$1 put into standards work.

Over two thirds of the companies indicated that standardization is being extended to more areas of company operations. That this is being accomplished through company standards committees using a standards engineering staff for administrative servicing is indicated by responses to three related questions. Two thirds of the companies reported no recent increase in either standards personnel or department budget. However, over half indicated that company standards committees are being widely used.

COMING MR&S PAPERS

Corrosion of Stainless Steel in the Presence of Concentrated Nitric Acid—Ch. Apert, Centre D'Essais Des Propulseurs.

The Scientific Application of Particle Accelerators to Nondestructive Testing—E. A. Burrill, High Voltage Engineering Corp.

Improvement in Fatigue Resistance of Aluminum Alloys by Mechanical Surface Prestressing—G. A. Butz and J. O. Lyst, Aluminum Company of America.

The Theta Specimen for the Determination of Tensile Strength of Brittle Materials—A. J. Durelli, Catholic University of America, and S. Morse and V. Parks, Illinois Institute of Technology.

Apparatus for Obtaining Mechanical Properties at High Temperatures—D. H. Fisher, R. L. Carlson, and F. C. Holden, Battelle Memorial Inst.

Stress Relaxation—Some New Test Methods for the Determination of This Mechanical Property Either in Tension or in Compression—G. R. Gohn and A. Fox, Bell Telephone Laboratories, Inc.

Determining the Weight and Analysis of Unalloyed and Alloyed Coating Layers on Hot-Dipped Aluminum Coated Steel—L. C. Ikenberry, Armco Steel Corp.

The Bend Test Properties of 43XX-Vanadium Modified and 5 per cent Chromium Sheet Steels—E. P. Klier, George Boras, and Jane Jellison, Catholic University of America.

A Penetrometer Study of the In Situ Strength of Clays—R. L. Kondner, Northwestern University.

Fracture Toughness Determination with "Shear-Cracked" Specimens—J. D. Morrison and J. R. Kattus, Southern Research Inst.

Improved Adiabatic Calorimeter for Concrete—David Pirtz, University of California.

A Statistical Comparison of the Wearing Characteristics of Two Types of Dollar Notes—E. B. Randall, Jr., and John Mandel, National Bureau of Standards.

A Model of the Mechanical Properties of Metals—F. B. Stulen, Curtiss-Wright Corp.

Tensile Impact Testing for Plastics—R. F. Westover, Bell Telephone Laboratories, Inc., and W. C. Warner, The General Tire & Rubber Co.

Errata

IN THE PAPER by P. J. Sereda, "Characteristics of Moisture Deposition on Corrosion Specimens," *MR&S*, Sept., 1961, pp. 719–723, several of the figure captions were misplaced. The captions should read as follows:

Fig. 1, p. 720, top row of photos, left to right: "(*1*) Zinc, 0.10 in.; (*2*) Stainless steel, 0.065 in.; (*3*) Zinc-plated steel, 0.035 in." Bottom row, left to right: "(*6*) Galvanized steel, 0.017 in.; (*5*) Aluminized steel, 0.030 in.; (*4*) Moisture-sensing element, zinc, 0.10 in."

Fig. 2, p. 720, top row of photos, left to right: "(*8*) Steel, 0.10 in., corroded; (7) Steel, 0.025 in., corroded; (*6*) Zinc, 0.025 in.; (*5*) Zinc, 0.05 in." Bottom row, left to right: "(*1*) Zinc, 0.30 in.; (*2*) Zinc, 0.20 in.; (*3*) Zinc, 0.10 in.; (*4*) Moisture-sensing element, zinc, 0.10 in."

Fig. 4, p. 721, top row of photos, left to right: "(*1*) Steel, corroded; (*2*) Zinc; (*3*) Stainless steel." Bottom row, left to right: "(*6*) Copper; (*5*) Galvanized steel; (*4*) Aluminized steel."

Fig. 5, p. 722, the caption under the lower right-hand photo should read "16½ hr" instead of "16 hr."

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Stainless Steel Unsullied by Time, Elements

After more than 30 years of experience, ASTM inspection team gives architectural stainless steel a clean bill of health.

THE USE of stainless steel in architectural applications was only a gleam in the manufacturer's eye in 1924, when ASTM held its first symposium on corrosion-resistant alloys. By 1929, when Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys began operation, type 302 stainless steel was being used in the body and spire of the Chrysler Building in New York, and other major installations quickly followed. In 1937 Committee A-10 felt the time was ripe to determine how these installations were holding up in service. An inspection committee was formed and made its first report in 1939.[1] In 1961, the report of the seventh inspection of buildings summarized experience with 30 years of exposure of stainless steel.

Under the Grime, Shine

The 1960 inspection first examined the oldest structure using stainless steel, the Chrysler Building in New York City. The type 302 stainless steel spire had not been cleaned since its erection in 1929–1930. The surfaces of the spire, which were examined through windows on the 71st floor, were covered with a black deposit, but there was no evidence of any rusting underneath. There was a small amount of superficial red deposit on the window sills, which was thought to be caused by chlorides.

At the 61st floor level, the surfaces of the tower were covered with dirt, but under the dirt there were practically no indications of pitting. The gargoyles had much less dirt adhering to their surfaces than the tower surfaces, presumably because they were projecting and were subject to better cleaning by the weather. There was no evidence of pitting on the surfaces of the gargoyles.

The Empire State Building, erected in 1931, made use of large amounts of type 302 stainless steel on the exterior. The pilasters on the tower were examined last year from the 89th floor level. These had never been cleaned, but there was no trace of corrosion on the south and west sides and there were only faint traces of pits on the east and north sides. The surfaces, in general, seemed to have retained their original mill finish.

The type 302 No. 6 finish mullions were examined on all sides of the building on the sixth-floor level. There was a dark dirt on the surface of the mullions that was more prevalent in sheltered parts of the building. Underneath this dirt there were a few light shallow pits which did not give any evidence of having worsened since the previous inspection in 1954.

From all indications, there has been practically no deterioration of the stainless steel on this building since its erection 29 years ago. From a distance, in spite of adhering dirt, the stainless steel shines brightly, particularly on sunny days.

Under the Dirt, Integrity

The 1960 inspection committee decided that steel used in industrial buildings should also be included in its itinerary. As an early example of the use of stainless steel, the main boiler house, Irving Works of U. S. Steel Co., Dravosburg, Pa., erected in 1938, was inspected. The roof and sides, both inside and outside, are covered with corrugated stainless steel sheets varying in gage from 18 to 29. Between the inside and outside sheets is a $\frac{3}{8}$-in. thick insulation. There are a few type 430 sheets in the building, but most of the sheets are austenitic stainless steel of various compositions and finishes. The building had never been cleaned and was entirely covered with dirt and grime to the extent that there was little metallic luster to the sides.

Examination of the surface after removal of dirt from several spots on the outside of the building revealed some very shallow pits in sheltered areas but no attack on the boldly exposed metal. At one location inside the building there were some rust spots, believed to have

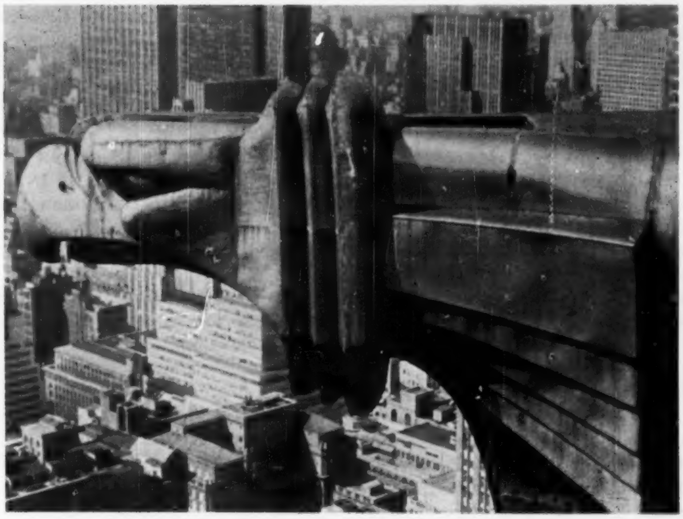
A-10 INSPECTION TEAM POSES BEFORE STAINLESS STEEL DOORWAY IN ATLANTIC CITY

(*Left to right*) C. P. Larrabee, W. G. Renshaw, Jane H. R. Rigo, A. C. Hamstead, and C. R. Mayne. Other members of the team are R. Doughton, Jr., J. H. McConnell, J. S. Pettibone, and G. M. Reigel.

[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 39, p. 197 (1939). Subsequent reports: Vol. 40, p. 118 (1940); Vol. 46, p. 593 (1946); Vol. 48, p. 137 (1948); Vol. 49, p. 138 (1949); Vol. 55, p. 160 (1955); and Vol. 61 (1960).

been caused by some salt which had been stored there, but had since been moved elsewhere. In the rest of the interior the stainless steel sheets showed no signs of corrosion.

Over 18 buildings were inspected in 1960, some in areas not previously covered by the committee—structures in Chicago, Ill.; Cleveland, Ohio; and Miami Beach and Indian River, Fla., that have been erected since 1946, using types 202, 302, 316, and 430 stainless steels. The committee decided not to examine buildings in Atlantic City, N. J., and the Reading Railroad "Crusader," stainless steel train this year in the light of satisfactory observations in the past.

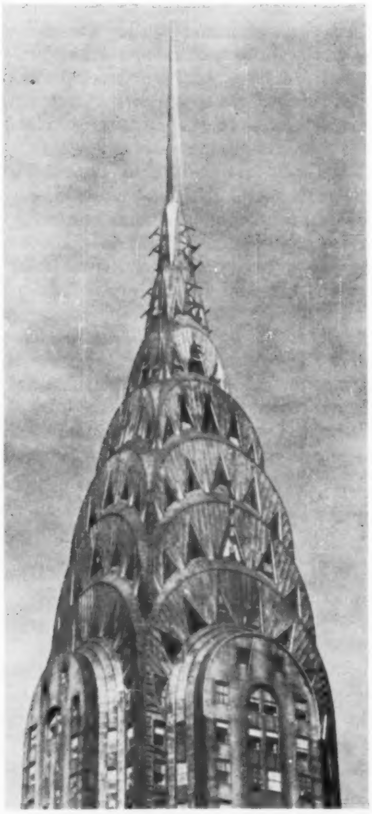


STAINLESS STEEL GARGOYLE BROODS IN PRISTINE SPLENDOR HIGH ABOVE MANHATTAN

Verdict: Favorable

The committee report summarizes 34 years of experience as follows:

1. Stainless steel in buildings retains its metallic luster and appearance beneath urban dirt and grime. With even limited cleaning there is no deterioration of the metal.
2. In industrial buildings, where appearance is not a big factor, stainless steel has practically an indefinite life, even without cleaning. Some shallow pits and light rust stains may be expected when chlorides are present, but the appearance of the building will be governed mainly by adhering dirt.
3. Even after long periods of neglect or abuse, stainless steel can be returned to a pleasing appearance by cleaning. Some slight pitting may then be discernible upon close inspection, the amount depending on the chlorides in the atmosphere and the type of stainless steel.
4. The use of cleaners containing chlorides should be discouraged. Incomplete removal of such cleaners will cause pitting and unsightly rusting, and complete removal from crevices is most difficult.
5. Applications of stainless steel in structures not subject to periodic cleaning should, as near as possible, be designed so as not to include crevices which may collect dirt. This dirt may hold some chlorides which can lead to superficial pitting.
6. In environments containing chlorides, stainless steels seem to develop a limited number of rust spots on boldly exposed areas beyond which no further deterioration in appearance occurs. The amount of rusting depends on the environment and the type of stainless steel. Type 316 stainless steel is the preferred grade for seacoast applications. The apparent cessation of rusting is thought to be associated with the cleaning action of the elements, the maximum being reached when the elements remove the chlorides at the same rate at which they are deposited.
7. Stainless steels are entirely adequate for architectural applications. The selection of the type should be governed by the environment, the desired maintenance of appearance, and the planned cleaning program.



STAINLESS STEEL EXTERIOR OF CHRYSLER BUILDING IS PRACTICALLY UNTOUCHED BY MORE THAN 30 YEARS' EXPOSURE TO THE ELEMENTS

Electrodeposited Metals (B-8)

AT THE MEETING of Committee B-8 on Electrodeposited Metallic Coatings and Related Finishes, held in Washington, D. C., September 15, plans were completed for a Symposium on Electroforming at the February, 1962, Committee Week in Dallas, Tex. (see p. 890). This symposium, the most comprehensive in this field to date, will cover all aspects of the process: the solutions used, the deposits and their properties, and their applications in many fields. A final session will be an open forum for discussion of points of interest and for showing motion pictures of this process, which has had considerable emphasis in recent years.

Two new atmospheric performance studies will begin this fall. The first, on decorative coatings on aluminum (AA 3003, 2024, and 6061), will determine the beneficial effects of heavy copper layers under nickel and over the aluminum to compare Watts nickel with duplex nickel undercoats and variations in the thickness of these. Principal aim of the second new program is to determine the most advantageous thicknesses of duplex-nickel coatings on zinc die castings.

An interlaboratory study to evaluate tests for the porosity of coatings has begun. Copper - nickel - chromium plated panels will be tested using the salt-spray (B 117), acetic acid salt-spray (B 287), Cass (B 368), Corrodkote (B 380), and sulfur dioxide (English) tests.

The development of standard adhesion ductility and stress test methods for electrodeposited coatings is being approached by evaluating a variety of tests in current use.

The committee is investigating three tests to determine the porosity of gold coatings. An adhesion test and a microscopic method for determining the thickness of gold coatings are also being studied.

The committee is exploring various methods for testing phosphate treatments on metal. Two new areas of interest discussed at the Washington meeting were vacuum metalizing deposits and the development of methods and specifications for shot-peened zinc coatings.

Refractories (C-8)

SUBCOMMITTEE II ON Research is obtaining information on the exotic uses and new applications of refractories so as to keep the committee informed. The subcommittee will review overseas work of interest and also activities in the education field that may have a bearing on refractories. The subcommittee is also studying quantitative methods that may be used to determine mullite ($3Al_2O_3 \cdot 2SiO_2$) using X-ray diffraction and microscopical techniques.

An alternate method for bulk density and porosity of hydratable granular refractories (using the mercury technique) has been completed for ballot. Methods are being developed to determine the porosity of chemically bonded brick affected by the boiling-water test, for modulus of rupture of air-setting plastic refractories, and for determining titanium dioxide and sulfur in refractories.

Interlaboratory work is being conducted to evaluate methods for the long-time load testing of refractories, the hydration of dead-burned dolimite for grain magnasite, and the determination of boron in magnesia refractories. A study is being conducted to determine the precision of the spalling test and to consider whether the procedure should be based on weight loss or the number of cycles of heating to produce cracks.

Approaches to the corrosion testing of glass-furnace refractories have resolved into static and dynamic test methods. The differences, if any, between gas and electric furnaces will also be investigated. Four dynamic methods are being evaluated using a standard soda-lime glass.

Two new projects have been initiated to standardize test furnaces and controls and to develop methods for abrasion testing of refractories.

Thermal Insulating Materials (C-16)

THE DEVELOPMENT of specifications for two types of thermal insulation—expanded polystyrene and rigid urethane foam—has provided a good example of inter-committee coordination. Since both of these materials are plastics, a coordinated program has been agreed upon between Committee C-16 on Thermal Insulating Materials and Committee D-20 on Plastics. During the meeting of Committee C-16 at Williamsburg, Va., September 25–27, representatives of Committee D-20 met with the responsible subcommittee of Committee C-16 for joint consideration of proposed standards for these materials.

Subcommittee T-VIII on General Standards has completed a proposed recommended practice for determining the outside diameter of thermal pipe insulation. Further study is being given to a proposed recommended practice for the measurement of squareness, trueness, and matching of pipe and block insulation.

The specifications for 85 per cent magnesia block-type thermal insulation (C 319) and 85 per cent magnesia molded-type thermal insulation for pipes (C 320) will be combined into one specification. A proposed method of test for structural insulating roof deck has been referred to Committee D-7 on Wood for final promulgation. A specification for insulating fiberboard formboard is in draft form.

A specification for $\frac{1}{2}$-in. nail base sheathing is being prepared for subcommittee consideration.

A proposed tentative method of test for determining density of fibrous loose-fill building insulations—the first ASTM standard for loose-fill insulation—was approved for letter ballot. A companion method, for determining the density of granular loose-fill building insulations was also approved.

Methods of test for thermal conductivity using the heat-flow meter are now ready for subcommittee letter ballot. A report will be prepared on the line heat method (probe), representing the joint efforts of Committees C-16 and D-20, for publication in *MR&S*.

In the area of special thermal properties the primary interest is in the development of a suitable fire test method. An extensive series of round-robin tests involving five laboratories is being continued.

Revisions in the Method of Test for Water Vapor Transmission (C 355) were accepted for subcommittee letter ballot. These revisions are in line with suggestions submitted by Committee D-20. The use of 1-mil Mylar as a reference material in the water vapor transmission test is being studied in a round-robin test program.

A proposed method for exterior exposure tests of finishes for thermal insulation is ready for subcommittee ballot.

The committee is attempting to determine the relative importance of various properties of heat insulation. It is recognized that adequate test methods should be developed before complete specification coverage can be obtained. Two surveys have been made which are in fair agreement in terms of listing properties of thermal insulation in the order of being essential, important, or desirable. Both indicate that the maximum and minimum temperature limits, thermal conductivity, and linear shrinkage are the leading essential properties.

Ceramic Whitewares and Related Products (C-21)

A SYMPOSIUM IN Tensile Strength jointly sponsored by ASTM Committees C-21 and C-25 and the American Ceramic Society was held in Toronto on April 26. A tension-test method based on one of the papers presented is being drafted. This exploratory method will be used as a basis for other approaches to this difficult problem.

Committee C-21 has organized a new task group on low-density ceramics. The first work of this group will be to develop modulus of rupture and flexure tests that can be used for foamed ceramics.

The interest aroused by the committee in the U. S. Potters Assn. and the Lead Industries Assn. has resulted in these two associations placing a contract with the Kettering Laboratories, University of Cincinnati, to develop data that can be used to support a standard method of test to determine the extractible lead in ceramic glazes.

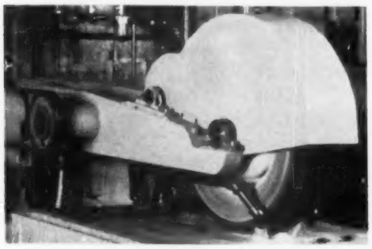
Methods for determining the 60-deg specular gloss of glazed tile and methods for determining linear dimensions of flat rectangular ceramic wall and floor tile were approved for committee letter ballot. The interlaboratory collaborative study that provided the basis for development of the 60-deg specular gloss methods is being presented as a paper on "Visual and Instrumental Comparison of Specular Gloss of Glazed Ceramic Tile" by Arno Illing and will appear in an early issue of *MR&S*.

Skid Resistance (E-17)

IT IS BECOMING more and more apparent that the timely activation of Committee E-17 on Skid Resistance just one year ago is filling a definite standardization need. The interest of members was expressed by excellent attendance and active participation at the latest meeting, held at the University of Tennessee, October 2-3. The Tennessee Highway Research Program, of which Committee E-17 Chairman E. A. Whitehurst is director, was the host for this meeting.

The key to standardization of methods of testing slipperiness or skid resistance is in the development of standard test

surfaces. Several types of materials have been used for test surfaces to date, such as plastics, steel, canvas, salt lick, glass, carborundum, and slag. The use of epoxy plates developed at the National Bureau of Standards shows considerable promise. This type of plate is inexpensive and therefore expendable. The desired characteristics in a standard test surface are ease of reproduction,

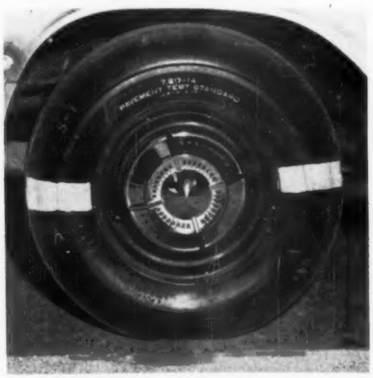


LABORATORY SKID MACHINE.

ease of shaping, magnitude of resistance of test surface relative to that of surfaces in the field, suitability for laboratory handling, durability, wettability, and effect on apparatus. Two types of manufactured material that may be considered as possible test surfaces are a silicon carbide coating on a waterproof backing and a glass-beaded coated surface.

The British Portable Tester (skid resistance) is now being used by various agencies in this country. A task force of eight such users will collect data on tests conducted with it. A number of the epoxy plates developed at the NBS will be made available to this task group for inclusion in the test program. In addition, samples of the silicon carbide and glass-beaded coated materials will also be distributed.

Various types of laboratory apparatus for determining coefficient of friction were reviewed, including both the pendulum and the sliding-block types. Three areas of activity were established within the scope of the Subcommittee on Laboratory Methods, namely, surface evaluation of (1) highways and airports, (2) industrial floors, and (3) pedestrian walkways.



ASTM STANDARD TIRE.

A demonstration of field test equipment was one of the highlights of the meeting. A series of tests were conducted on a section of new concrete pavement not yet opened to traffic, with equipment furnished by the Tennessee Highway Research Program, the Virginia Council of Highway Investigation and Research, and General Motors Corp. The demonstrations included a series of test runs on three pieces of equipment to establish the coefficient of friction at various speeds. Stopping-distance tests were conducted using the Tennessee equipment only. In these tests both the ASTM standard test tire and conventional tires were used. A field correlation study is planned for some time in August, 1962, in Virginia under the direct sponsorship of the Virginia Council. The Highway Research Board and Committee E-17 will be closely associated with this study. Its purpose will be to determine the variations among field equipment used for determining coefficient of friction and to establish causes for differences.

It was reported that 36 ASTM test tires have been sold to date, and it is expected that a new lot will now be manufactured. In the study of tire characteristics and their significance, the next objective will be to compare data on the use of the standard tire from the various agencies now using them.

Porcelain Enamel (C-22)

PORCELAIN ENAMEL samples are being sent to five cooperating laboratories as part of a program to determine the validity of the present proposed reboil test for porcelain enameling steels. The samples have a heavy, medium, and light tendency to reboil, and no reboil tendencies. It is realized that the composition of the enamel itself frequently plays an important role in determining the reboil characteristics of the steel.

The proposed test for determining the continuity of porcelain enamel coating by high- and low-voltage tests has been completed for balloting within the subcommittee.

MATERIALS SCIENCES

X-rays, Electrons, and Microstructure

A NUMBER OF items in the news recently all have to do with the microstructure of metals or indeed of any crystalline element or compound, the elucidation of which is so well aided by X-ray diffraction and more recently by the electron probe. An even newer technique involving low-energy electrons diffracted from a surface and accelerated by a strong magnetic field onto a fluorescent screen promises to aid understanding of catalysis and corrosion. L. H. Germer of Bell Telephone Laboratories, developer of the technique together with co-worker A. U. MacRae, told about it at the International Conference on Magnetism and Crystallography held in Kyoto, Japan, late in September. Dr. Germer said that the diffraction pattern produced on the screen gives the arrangement of the first monolayer of atoms on the surface of the specimen. It thus provides a powerful new tool for study of surface reactions, giving a detailed picture of arrangement of atoms entering into the reactions.

In their Kyoto paper Drs. Germer and MacRae reported on studies of oxygen and hydrogen adsorption on a nickel crystal. They found that after a monolayer of oxygen had been absorbed, nickel atoms diffused to the surface, producing an orderly arrangement containing either one or two oxygen atoms for each nickel atom. The arrangement containing equal numbers of oxygen and nickel atoms proves to be remarkably stable, persisting up to temperatures at which nickel evaporates rapidly. The Bell scientists found, however, that the oxygen can be easily removed by hydrogen at moderate temperatures, and that the hydrogen in turn is removed by slight heating, leaving a perfectly clean surface.

Another participant in the international conference in Japan was W. L. Fink, former national director of ASTM and currently chairman of the Joint Committee on Chemical Analysis by Powder Diffraction Methods. Dr. Fink told the conference about the Joint Committee's work in the collection editing, and dissemination of powder diffraction data for identification of crystalline substances by their diffraction patterns. The Joint Committee is a cooperative venture with the American Crystallographic Assn., the Institute of Physics (British), and the National Association of Corrosion Engineers. Proceeds from the sale of diffraction data, which average over $100,000 annually, are used to support

research to add new data to the file and to defray editorial and publication expenses. Dr. Fink's trip to Japan gave him an opportunity to line up some Japanese contributors to the data file. Arrangements have already been made with Prof. Taheo Fujiwara, Defense Academy in Japan, to supervise projects established in Japan. There is active cooperation in this joint effort also from The Netherlands and from several groups in England. The committee is endeavoring to obtain the widest possible participation and invites inquiry from those interested.

Getting back to the elusive electron, which more and more is being controlled to reveal the fine structure of matter, big science now steps in, and some of the fruits of development of powerful particle accelerators for fundamental studies in science may now be made to pay off in more practical ways. A. E. Burrill of High Voltage Engineering, Inc. will tell how particle accelerators may be used for nondestructive testing of materials in a coming issue of *MR&S*. Watch for it.

The Fleas' Fleas Have Fleas

The Materials Science Series of ASTM symposium publications, the second of which is now in press, are a rich source of scientific information about materials. As a sample from the one next to be issued, "Major Effects of Minor Constituents . . ." we quote from the paper by Wyman and Moore of the National Bureau of Standards, "Impurity Effects in High-Purity Metals."

. . . in several areas of metal science . . . impurity effects are of profound significance to the properties of the basic substance. From the standpoint of materials science . . . information [on our state of knowledge] should be evaluated in terms of two factors: (1) the rate at which the science of metals is advancing, and (2) what is needed to enhance our materials knowledge.

To evaluate our progress, one may note that in 1950 Schumacher in his Institute of Metals Division Lecture entitled "Metallurgy Behind the Decimal Point," never used the term "parts per million."

In his 1953 Gillett Lecture before this Society, Strauss predicted: "Be not surprised if very soon there is discussion in terms of parts per billion, or beyond." Strauss used the term ppm twice in this lecture. Today, impurity levels in the low ppm bracket are items of specification for a number of materials, and ppb is of common usage in semiconductor work.

This increase of sensitivity in the detection of impurity effects is due to enhanced capabilities in the preparation and analysis of substances of decreasing impurity content. Thus when it does become possible to more closely approach "ideal" purity in a substance, then, and only then, can the inherent properties of the material be established and the specific effects of additive materials be completely evaluated.

Whatever means one may use to evaluate the rate at which materials science is advancing, it is quite obvious that the engineering demand for materials is far in advance of present capabilities to supply these materials. Furthermore, the demands are advancing at a faster rate than that at which new materials can be devised. Thus, whatever may be the present rate of increase of materials knowledge, it is far too low. As a consequence, materials science is presently double-harnessed with obligations, first, to catch up with engineering demands, and secondly, to endeavor to surpass these demands and to keep in the lead.

What must be done can be answered either by plain common sense or through sophisticated analyses, because the answer is the same: It is imperative that much greater research effort be directed to those areas from which the properties and behavior of materials of "ideal purity" can become known.

To do this, there must be more basic research on more highly purified metals by means of far better methods and means of analysis. Thus, this pursuit of impurities to increasingly lower levels of content becomes akin to Dean Swift's quote:

"So, Nat'ralests observe, a Flea
Hath smaller fleas that on him prey,
And these have smaller fleas to bite 'em,
And so proceed *ad infinitum*."

DMS Membership

On September 19, 1961, when the Board of Directors officially approved the by-laws of the Division of Materials Sciences, membership in the Division was authorized. The by-laws specify that all individual members of the Society are eligible and organizational-type members may appoint one individual to membership in the Division. Membership application forms may be obtained from the Society's Headquarters 1916 Race Street, Philadelphia 3, Pa.

NEW ASTM PUBLICATIONS

Knock Testing Manuals Being Updated

1961 Supplement to Manuals of Engine Test Methods for Rating Fuels

128 pages, hard cover, price $4.50, to members $3.60.

This supplement contains information that will bring up to date the 1960 Manual for Rating Motor Fuels by Motor and Research Methods, the 1958 Manual for Rating Aviation Fuels by Supercharge and Aviation Methods, and the 1959 Manual for Rating Diesel Fuels by the Cetane Method. This supplement has been prepared by Research Division I on Combustion Characteristics of Committee D-2 on Petroleum Products and Lubricants. It includes all changes and additions to these three manuals that have been approved by Committee D-2 and the Society up to July 1, 1961.

For the 1960 Motor Manual, this supplement includes the current Motor Method for Octane Numbers 100 and Below (D 357), and for Octane Numbers Above 100 (Proposed); also the Research Method for Octane Numbers 100 and Below (D 908), and for Octane Numbers Above 100 (D 1656). In addition, there are included two new proposed methods—one for determining knock characteristics of motor fuels by the research method equipped with split-head cylinder, and a test for knock characteristics of motor fuels by the 1170 severity method. Several new tables are also included. These are for conversion of micrometer readings to compression ratio, conversion of digital counter readings to micrometer settings, and average compression pressures for motor and research engines. The new manual also includes changes in four of the six appendices to the Motor and Research Manual.

For the 1958 Aviation and Supercharge Manual, the supplement includes the current Supercharge Method (D 909) and Aviation Method (D 614). In addition, changes are given for four of the six appendices. Two new tables cover ASTM aviation ratings of standardization fuel blends of benzene, *iso*-octane, *n*-heptane, and tetraethyllead, and specifications for ASTM knock test reference fuels.

For the 1959 Cetane Manual, the supplement includes the latest Cetane Method (D 613) and changes in four of the six appendices. Two new tables include a list of replacement changes, manufacturing tolerances, and replacement limits for cylinder assembly parts.

All those having copies of one or more of the three engine test manuals should obtain this 1961 supplement in order to bring their copies up to date.

1961 Book of ASTM Standards Now Rolling off the Presses

The standards bookshelf is beginning to fill. Three parts (1, 7, and 10) are now available. These will be followed shortly by parts 4 and 6.

THE 1961 EDITION of the world's most complete and useful compendium of information about materials—the ASTM Book of Standards—is now coming off the presses. Three of the eleven parts are already available, and two more will follow shortly. The 3000 standards in these eleven volumes are thus beginning to flow into the main stream of the nation's materials commerce, where they fill their indispensable role as everyday, practical, working documents.

In the following list of titles of the eleven parts, those now available are shown in boldface type. In some cases, number of pages and of standards are approximate.

Part 1—Ferrous Metals Specifications (1652 pages, 304 standards), list price $23, to members $18.50[a]

Part 2—Nonferrous Metals Specifications, Electronic Materials (1574 pages, 292 standards)

Part 3—Methods of Test for Metals (Except Chemical Analysis) (1186 pages, 151 standards)

Part 4—Cement, Lime, Gypsum, Mortar, Concrete, Mineral Aggregates, Bituminous Materials, Soils (1717 pages, 391 standards)

Part 5—Masonry Products, Ceramics, Thermal Insulation, Acoustical Materials, Sandwich and Building Constructions, Fire Tests (1352 pages, 304 standards)

Part 6—Paper, Packaging, Flexible Barrier Materials, Adhesives, Wood, Cellulose, Casein, Leather (1448 pages, 286 standards)

[a] Price for part in addition to the part received by member through membership privilege.

Part 7—Petroleum Products and Lubricants (1658 pages, 220 standards), list price $23, to members $18.50[a]

Part 8—Paint, Naval Stores, Coal and Coke, Gaseous Fuels, Industrial Aromatic Hydrocarbons, Engine Antifreezes, Industrial Chemicals (1911 pages, 410 standards)

Part 9—Plastics, Carbon Black (1096 pages, 211 standards)

Part 10—Textiles, Soap, Sorptive Mineral Materials, Halogenated Organic Solvents, Industrial Water, Atmospheric Analysis, Wax Polishes (1916 pages, 309 standards), list price $23, to members $18.50[a]

Part 11—Rubber, Electrical Insulation (1868 pages, 82 standards)

Textile Materials

ASTM Standards on Textile Materials, 1018 pages, hard cover, price $10.00, to members $8.00.

Included among the ten new tentative methods are procedures for determining yarn number (skein method), yarn severance in woven fabrics, dimensional changes in woven and knitted textiles (excluding wool), staple length of wool tops, estimation of effective gage lengths in single-fiber testing, estimating maturity and weight per unit length of cotton fibers by causticaire method, moisture content and moisture regain of lint and seed cotton (oven method), and pH of aqueous extracts of wool and similar animal fibers.

Of particular interest is a list of commercial moisture regains for textile fibers. These values are primarily intended for determining the commercial weight of a specific fiber when the fiber is sold on this basis. Included also is a recommended practice for standard moisture content of wool and its products.

A new standard method covers procedures for the determination of the average fiber diameter and the fiber diameter distribution of wool and mohair in their various forms by use of the microprojector. This method is also applicable to allied fibers such as cashmere, alpaca, camel hair, etc. It is used for determining the fineness of wool, wool tops, and mohair tops, the specifications for which are brought up to date in this book.

The five proposed methods cover procedures for calculating number of tests to be specified in determining average quality of a textile material, evaluation of properties related to the hand of soft-finished woven fabrics, recovery of textile fabrics from creasing using the roller pressure apparatus, cotton content of asbestos textile materials (referee method), and length and length distribution of cotton fibers by the short method array. A separate appendix describes the Tex system for designation of yarn number. A valuable addition to the book this year is a series of infrared spectra for textile fibers used with the methods for identification of fibers in textiles.

The general subjects covered are nonwoven fabrics, hosiery, carpets, tire cord, asbestos textiles, bast and leaf fiber textiles, cotton, wool, glass, and man-made fiber textiles. A group of definitions and test methods for zippers prepared by Committee D-13 this year are published in a separate reprint.

The book also contains a list of the personnel of Committee D-13, regulations governing the committee, scope of D-13 and its subcommittees, and an index.

ASTM Definitions and Methods of Test for Zippers

Special Reprint, Committee D-13, heavy paper cover, 48 pages, price $1.50, to members $1.20.

THIS SPECIAL reprint contains test methods for an important accessory used with textiles that were developed by Committee D-13 on Textile Materials in cooperation with the Slide Fastener Assn. after a study extending over a period of about five years. The methods cover practical tests for colorfastness to laundering, drycleaning, light, rubbing or crocking, and perspiration. Resistance to abrasion and durability of finish of zippers to laundering, drycleaning, and salt fog are also included. Other methods cover measuring procedures, strength tests, and operability of zippers. An extensive list of definitions is also included.

Petroleum Products and Lubricants

ASTM Standards on Petroleum Products and Lubricants (Vol. 1), 1308 pages, hard cover, price $10.50, to members $8.40.

THE 1961 EDITION of the Compilation of ASTM Standards on Petroleum Products and Lubricants includes 177 standards and tentatives and 18 proposed methods.

Among the new tentatives published for the first time are specifications for liquefied petroleum gases (LPG) and for commercial hexanes, and eight new methods. The methods include tests for odor and peroxide number of paraffin wax, gloss of waxed paper, copper corrosion by LPG, volatility of LPG, naphthalene hydrocarbons in aviation turbine fuels by ultraviolet spectrophotometry, roll stability of lubricating greases, and amyl nitrate in diesel fuels.

Published as information are tests for: separation of tetraethyllead and tetramethyllead in gasoline; residue in LPG (end point index method); sampling turbine engine fuel for cleanliness evaluation; barium, calcium, and zinc in lubricating oils and additives (complexometric titration); hydrocarbon types in low-olefinic gasolines by mass spectroscopy; hydrocarbon types in olefinic gasolines by mass spectrometry; solid point of aviation turbine fuels; vapor pressure of petroleum products (micro method); and shear stability of polymer-thickened oils.

Particularly noteworthy are two proposed methods for knock characteristics of motor fuels, by the split head cylinder engine, and by the 1170 severity method. Other proposed methods cover procedures for analysis of natural gas by gas chromatography, and tests for oxidation stability of steam-turbine oils by rotating bomb, accelerated stability test for distillate fuel oil, and particulate matter in aviation turbine fuels.

Also of particular interest are three methods for analysis of rubber extender oils being jointly considered by Committees D-2 and Committee D-11 on Rubber and Rubber-like Materials for use in synthetic rubber manufacture. These cover an adsorption chromatographic analysis, the modified Rostler-Sternberg method for composition, and the clay-gel adsorption chromatographic method for characteristic groups in rubber extender oils.

Methods extensively revised this year cover sampling procedures, gravimetric and polarographic methods for lead antiknock compounds in gasoline, mercaptan sulfur in aviation turbine fuels, and Conradson carbon residue of petroleum products.

Rubber Products

ASTM Standards on Rubber Products, 1174 pages, hard cover, price $12.00, to members $9.60.

THE 20TH EDITION of the Compilation of ASTM Standards on Rubber Products includes all the 179 ASTM standards and tentatives relating to these materials. This new edition contains five tentatives completed in 1961—specifications for rubber rings for asbestos-cement pipe and methods for: tubular oven aging of elastomers and plastics, adhesion of vulcanized rubber to single-strand wire, free 2-mercaptobenzothiazole in benzothiazyl disulfide rubber vulcanization accelerator, and total 2-mercaptobenzothiazole of commercial benzothiazyl disulfide rubber vulcanization accelerator.

This edition also includes two specifications and one method added to the book since 1960. The two specifications cover latex-dipped goods and coatings for automotive applications, and carbon blacks used in rubber products (prepared jointly with Committee D-24), and the method of test is for solubility of organic chemicals. Definitions of terms relating to rubber and rubber-like materials, and revision of the methods for chemical analysis of rubber and of synthetic elastomers also appear in this book.

Standards are included on the following subjects: processibility tests, chemical and physical tests, aging and weathering, low-temperature tests, electrical tests, automotive and aeronautical rubber, packing and gasket materials, hose and belting, tape, electrical protective equipment, coated fabrics, insulated wire and cable, hard rubber, urethane foam, sponge and cellular rubbers, adhesives, synthetic elastomers, and compounding materials.

The book also includes 22 general methods prepared by Committees E-1

on Methods of Testing and E-11 on Quality Control of Materials.

Appended to the book are proposed methods of testing rubber thread, also Regulations Governing Committee D-11, a list of the scopes of D-11 subcommittees, and the personnel of the committee. The book is completed by a valuable index which is an excellent source of reference for the latest standards on specific subjects.

ASTM Tables for Volume Reduction of Contents of Positive-Displacement Meter Prover Tanks

Special Publication, Committee D-2, 48 pages, 7 by 10 in., heavy paper cover with spiral binding, price $2.50, to members $2.00

THIS PUBLICATION comprises two tables of multipliers for converting to 60 F the volumes of petroleum and petroleum products measured at temperatures between 0 and 125 F in insulated mild steel prover tanks for positive-displacement meters. Table A is designed for use with liquids generally handled in vessels vented to the atmosphere and is entered with API gravities. Table B provides factors for computing the volume of a steel tank at an observed temperature. These tables have been calculated on the basis that the tank has been calibrated at 60 F. Also, it has been assumed that the tank-shell temperature and the mean temperature of the contents are identical during the time of volume measurement.

Because of the increasing use of positive displacement meters for the measurement of petroleum products, it was considered a great convenience to have available these tables applicable to measurement of volume in meter prover tanks for establishment of meter factors. These tables were prepared in cooperation with the API Petroleum Fluids Measurement Committee's Working Group on Liquid Metering. They combine the expansion characteristics of steel with those of petroleum products as used in the ASTM-IP Petroleum Measurement Tables (D 1250–56).

Electrical Contacts

1960 Supplement to the Bibliography and Abstracts on Electrical Contacts, STP 56-0, 47 pages, paper cover, price $4.50, to members $3.60.

THE FIRST COMPLETE bibliography on this subject was published in 1952 covering the world literature on contacts for the period 1835–1951. Each year since, supplements have been issued, bringing up to date this useful and specialized bibliography. The present supplement includes 187 abstracts of which 172 were of papers and books published in 1960 and 15 picked-up items not included in earlier supplements.

The preparation of the supplement was under the guidance of a committee consisting of E. I. Shobert, II, Stackpole Carbon Co. (chairman), C. K. Strobel, Westinghouse Research Laboratories, and L. F. Neely, P. R. Mallory & Co., Inc.

Abstracts are indexed by authors and according to the following subjects:

- Books covering subject electric contacts
- Electric contacts—general
- Contact materials—fabricated
- Contact materials—powdered metals
- Circuit breaker design
- Circuit breaker testing
- Contactor or relay design
- Stationary or fixed contacts
- Sliding contacts—slip rings
- Sliding contacts—commutation
- Contact resistance
- Electric arc theory as applied to contacts
- Glow discharge theory
- Contact wear
- Circuit and circuit parameters as applied to contact operation
- Friction and lubrication

DISTRICT ACTIVITIES

CENTRAL NEW YORK

AN INTERNATIONAL project for sharing vast natural resources illustrates to the peoples of the entire world the friendly relationship between the United States and Canada. This is the St. Lawrence Power Project near the City of Massena, N. Y. Three major dams, many miles of dikes, and millions of yards of channel excavation control one of the great rivers of the world and have created the 60-sq-mile Lake St. Lawrence, a vital link of the St. Lawrence Seaway. At the end of this lake, operating under a head of 85 ft, is the Robert W. Moses and Robert H. Saunders Power Dam. This dam, 3300 ft long with 32 turbine generators, rated at 1,880,000 kw, is the second largest power dam in the world, being surpassed only by Grand Coulee. At opposite ends of the dam are two power stations, one operated by the Power Authority of the State of New York, the other by The Hydro Electric Power Commission of Ontario. Adjacent is the St. Lawrence State Park and the Dwight D. Eisenhower Lock of the Seaway.

A tour of this awe-inspiring project was tied in with a technical session on the "St. Lawrence Power Project" sponsored by the Central New York District on October 6 and 7, 1961. Luther B. Cliffe, resident engineer, Power Authority of the State of New York, was the featured speaker at the technical session following a dinner on the evening of October 6. Those taking the tour on October 7 were privileged to walk out on the face of the dam to its center, where a memorial plaque is centered between flags of the United States and Canada. The men were also conducted on a tour under and within the dam structure where the power generating equipment was operating.

At the dinner, Student Memberships in ASTM were awarded to six outstanding students of the Clarkson School of Technology. The presentation was made by R. A. Schatzel, past-president of ASTM. Numerous ASTM members from Canada attended the dinner, and R. F. Leggett, National Research Council of Canada, an ASTM Director, paid tribute to the spirit of friendliness between the two countries on a national level as well as on an individual level. He held this relationship as something which other countries of the world should emulate. A coffee talk by J. W. Caum of the ASTM Headquarters Staff brought the members up-to-date on recent developments in the Society. G. H. Harnden, chairman of the Central New York District Council, presided at the ceremonies following the dinner. The assemblage was also honored by the presence of T. S. Fuller, president of the Society in 1951–52.

Mr. Cliffe discussed the authorization and initiation of the St. Lawrence Power Project, the international implications, relationship with the seaway, construction features, and operational problems. The flow of water from Lake Ontario via the St. Lawrence River into Lake St. Lawrence is controlled by the Iroquois Dam (2335 ft long) so that waterfront owners on the shores of Lake Ontario and the Thousand Island area of the St. Lawrence River are not adversely affected. Actually, the flow is so constant that very little control is necessary. The Long Sault Dam, which regulates a bypass for the waters of Lake St. Lawrence around the power dam, is 2960 ft. long and 114 ft. high. The Canadian and U. S. power supplies are connected by a tie line which spans the river just below the power dam. The tie line itself is a modern miracle which has a one-mile

single span dropping 400 ft at its center in crossing the river. The Power Project works under a set of regulations which were mutually agreed upon to protect the waterfronts extending from Lake Ontario to Quebec Harbor and to provide sufficient water depths for the efficient operation of the St. Lawrence Seaway.

C. L. Kessler, Aluminum Company of America, was responsible for the meeting and tour arrangements.

Apology

In "Technical Committee Officers," *MR&S*, Sept., 1961, the cutlines for the officers of Committees E-2 on Emission Spectroscopy and D-27 on Electrical Insulating Liquids and Gases were inadvertently interchanged. Our apologies to C. A. Johnson, H. W. McCulloch, Jr., R. E. Michaelis, and D. W. Henthorn, who are correctly identified below.

TECHNICAL COMMITTEE OFFICERS

Officers of Committee E-9 on Fatigue

Left to right: F. B. Stulen, vice-chairman, Curtiss-Wright Corp.; H. J. Grover, chairman, Battelle Memorial Inst.; R. F. Brodrick, secretary, Lessells and Associates, Inc.; *missing;* S. M. Marco, assistant secretary, The Ohio State Univ.

Officers of Committee C-12 on Mortars for Unit Masonry

Left to right: H. C. Plummer, chairman, Structural Clay Products Inst.; P. L. Rogers, second vice-chairman Riverton Lime and Stone Co., Inc.; C. U. Pierson, Jr., secretary, Marquette Cement Mfg. Co.; *missing:* P. M. Woodworth, first vice-chairman, The Waylite Co.

Officers of Committee E-5 on Fire Tests of Materials and Construction

Left to right: G. W. Shorter, vice-chairman, National Research Council of Canada; H. D. Foster, (deceased) chairman; I. A. Benjamin, secretary, Granco Steel Products.

Officers of Committee D-27 on Electrical Insulating Liquids and Gases

Left to right: C. A. Johnson, secretary, Socony-Mobil Oil Co. (retired); H. W. McCulloch, Jr., vice-chairman, Shell Oil Co., Inc.; *not present,* E. R. Thomas, chairman, Consolidated Edison Co. of New York, Inc.; R. M. Frey, membership secretary, Line Materials Industries.

Officers of Committee E-2 on Emission Spectroscopy

Left to right: R. E. Michaelis, chairman, National Bureau of Standards; D. W. Henthorn, secretary, Vanadium Corporation of America; *not present,* R. W. Smith, vice-chairman. General Motors Corp.

Indian Symposium on Ferro-alloys

IN ORDER TO focus attention on the latest developments in the field of ferro-alloys so that plans can be laid for establishing a full-fledged ferro-alloy industry in India, the National Metallurgical Laboratory of India will hold a Symposium on the Ferro-alloy Industry in India, early in February, 1962.

At present, only ferro-silicon and standard high-carbon grade of ferro-manganese are being commercially produced in India—beyond this there is hardly any industrial-scale production of high-grade ferro-alloys. India has substantial resources, however, for the production of a number of other types of alloys.

It is hoped that the symposium will bring together engineers, metallurgists, industrialists, consumers, and planners so that they can discuss problems of raw materials, processing techniques, quality and range of output, and market demands which would face the industry in India. Invitations are being extended to technologists, metallurgists, and research scientists both in India and abroad to attend the symposium and contribute papers for discussion. Information can be obtained from the director, National Metallurgical Laboratory, Council of Scientific and Industrial Research, Jamshedpur, India.

LETTERS

Ductility of Carboloy

¶ In regard to my recent article on "Testing Carboloy—Some Early Experiences," [*MR&S*, July, 1961, p. 546] it has just been called to my attention that the reference was given incorrectly for that paper that discussed ductility of cemented carbides [footnote 1 of the article]. I was in Germany at the time I wrote the article and did not have an opportunity to look it up. I am still unable to do so because I have not yet unscrambled my files, so I would appreciate it if you could attend to it.

[*The correct reference is: R. P. Felgar and J. D. Lubahn, "Mechanical Behavior of Cemented Carbides," Proceedings, Am. Soc. Testing Mats., Vol. 57, pp. 770–790 (1957)*—Ed.]

Stress-Corrosion Cracking Test

¶ We have carried out an exploratory investigation on the interesting simple stressed-loop stress-corrosion tests described by D. H. Thompson ["A Simple Stress-Corrosion-Cracking Test for Copper Alloys," *MR&S*, Feb., 1961, p. 108], and we enclose a copy of our report giving the results of our findings. You will see that our main criticism is that, using simple apparatus of the type described, difficulty was experienced in controlling the humidity of the test cabinet. Humidity appears to be a critical factor in causing cracking, and one test ceased to function when the test cabinet was left near an open window and a dry deposit formed inside the loop. We should welcome your comments in due course and whether you have been able to overcome the difficulty in question.

E. S. LLOYD
Joseph Lucas (Electrical) Ltd.
Birmingham, England

(*Reply by Mr. Thompson*).—I have not had any difficulty with maintaining adequate humidity in the test. The jars containing the test specimens are kept away from sunlight, thermal radiation, and either hot or cold drafts. Actually, they usually repose, during a test, in a chemical fume hood. The intensity of the incoming draft is minimized by leaving the front of the hood open. I should like to emphasize that at the start of a test, each sample is completely covered with a film of water and a good-sized bead of water rests in the saddle of the loop. I have calculated that the relative humidity in the enclosed space, above concentrated ammonium hydroxide solution, is about 70 per cent. Hence I find it difficult to understand how a specimen could have become actually dry even if the container were left in a cold draft.

Karl Friedrich Gauss

(1777–1855)

PROFESSOR OF ASTRONOMY and director of the observatory at Göttingen, Gauss carried on researches in electricity, mathematics, and astronomy. Many consider him, with Archimedes and Newton, one of the three greatest mathematicians of history. At the age of 12 he was criticizing the foundations of Euclidean geometry; at 15 he gave a rigorous proof of the binomial theorem; at 18 he invented the method of least squares; at 22 he had invented elliptic functions.

This is one of a series of photographs from a collection compiled by Prof. Jasper O. Draffin and displayed in the Arthur N. Talbot Laboratory, University of Illinois.

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A sharp eye for infrared

The decision to announce off-the-shelf availability of *f/1 Irtran-2 Aspheric Lenses* in 2- and 3-inch focal lengths has been reached in struggle against deeply rooted inhibitions. In the photographic film and paper trade we are habituated to a longer silence before the first blast of the trumpets. Infrared technology hates to wait, however.

These Irtran-2 lenses transmit usefully from 2μ to 14μ. Sharpness was the goal. For both lenses, the minimum circle of confusion *computes* at less than .001″ for any wavelength from 4.25μ to 10μ.

Much care and a valuable ingenuity have been exercised in impressing our tenth-degree equation upon the concave side of these meniscus lenses, in grinding and polishing the spherical convex side, in placing the center of the spherical curvature on the axis of the asphere, in maintaining the center thicknesses at the 9.1 mm and 10.4 mm values respectively that the calculations assume, in the optical homogeneity of the Irtran-2 material. More than this we cannot claim. To the extent that the care and ingenuity have succeeded in making the calculations represent the actuality, the circle of confusion is less than .001″. The customer's willingness to take a chance that we have hit it will, in good sense, depend on how badly his project needs a 2μ-14μ infrared image of high definition and high aperture.

In the lead sulfide region, the sharpness does not compute to be as good as farther out in the infrared. Yet we have customers who use the lenses there and are happy with confusion-circle minima as large as .008″.

We have said enough to establish our frankness and to indicate whether there is any need for you to burden the long lines to Rochester, N. Y., LOcust 2-6000, Extension 5166, which is one way to reach Eastman Kodak Company, Special Products Division. Bear in mind that Irtran-2 material has a hardness of 354 Knoop, is not at all brittle, withstands thermal shock and the solvent action of water, and can get very hot without losing transparency or giving off toxic fumes.

THIS paper

"*My husband sells oscillograph paper. Competition is fierce. He comes home beat every night.*"

Few overhearing her would know what the poor soul is talking about, yet she speaks the truth. With research and development activity now constituting such a respectable fraction of the Gross National Product, oscillographs probably outnumber pickle barrels in this country at the present time. Oscillographers are correspondingly numerous. Methods that one sect of oscillographers prefers above all else another sect can't see for dirt. One sect prefers automatic oscillogram processors. Paper manufacturers like us find their favor worth competing for. Therefore we announce a new advance in media for their use.

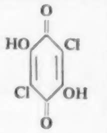
An advance in the old art of papermaking came first. Then new emulsions were devised to work properly with the new base. Then proper processing chemicals were devised for the new emulsions. Then the combination was extensively proved out under practical conditions of use by parties interested only in end results and hardly at all in the how and why. They found that

1. THIS paper dries thoroughly at high processor speeds *without creases.* ***180 in./min. is not too fast.***
2. THIS paper gives trace lines that stand out as black as the ace of spades. ***Background is nice and clean.***
3. THIS paper isn't fussy about how long it sits around before use. ***O.K. to keep plenty on hand.***
4. THIS paper is rugged. ***No cracking, no crumbling.***
5. THIS paper holds its dimensions. ***Justifies careful measurement.***

"THIS" won't do for a trademark. (The code name for the field trials was "Kind 1534.") Let's call it Kodak Ektaline Paper. *It comes in the two usual speeds for oscillographs,* Kodak Ektaline 16 Paper *and* Kodak Ektaline 18 Paper. Kodak Ektaline Chemicals *come as liquids. The stabilization principle used in the automatic oscillogram processors came from Kodak, too. An inquiry to Eastman Kodak Company, Photorecording Methods Division, Rochester 4, N. Y., puts everything in place right up to the moment.*

The chloranilate way to cations or anions

The earliest paper on chloranilic acid that we have excavated out of the literature appeared 118 years ago. It is a 90-page beaut that seems to have left nothing more to be said on the subject for 102 years. The next paper came out in Brazil and is only two pages long, but it loosened the plug of apathy. Now we can send you a list of 29 references on chloranilic acid to determine Ca^{++}, Zn^{++}, Zr^{++++}, Mo^{++++++}, Sr^{++}, Ba^{++}; and on various metal chloranilates to determine SO_4^{--}, F^-, PO_4^{--}, Cl^-, Ca^{++}, Pb, and even EDTA itself.



At low pH, *Chloranilic Acid* (Eastman 4539) is intensely purple, absorbing strongly at 520-550mμ and even more strongly at 290-340mμ.

The free acid (and acid it assuredly is, with a pH at saturation of 2) stands intermediate in solubility between *Sodium Chloranilate* (Eastman 8223) and the heavier metal salts of the acid. This happy circumstance lends itself to all manner of clever exploitation by the analyst. Buffering and tinkering with the solvent system help further.

Some cations, such as molybdenum and zirconium, form characteristic highly colored complexes with chloranilic acid.

Some anions, such as fluoride, coordinate themselves to the lanthanum and thorium salts of chloranilic acid to yield other distinctive and highly colored complexes. *Thorium Chloranilate* (Eastman 8257) is said to permit detection of 0.01 ppm of fluoride. (It should sell well, since F^- possesses the rare distinction among anions of being a political issue.)

Other anions, such as sulfate, can precipitate the cation from an appropriate chloranilate salt solution, freeing the highly colored acid chloranilate ion which thereupon tells the tale colorimetrically of how much anion was present. *Barium Chloranilate* (Eastman 7508) does this for sulfate, *Lanthanum Chloranilate* (Eastman 7629) for phosphate, *Mercuric Chloranilate* (Eastman 7504) and *Silver Chloranilate* (Eastman 7838) for chloride.

Let's have a little action here. Let's not just send for the list of 29 references. You can read every one of them and it will still be all in your mind unless you actually get hold of the reagents. Do you know how much our minimum-size packages of all seven of the items mentioned add up to in money? $23.10, that's how much. The place is Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company), which can also supply a copy of Eastman Organic Chemicals List No. 42 that goes into more price detail. (Look under 2,5-Dichloro-3,6-dihydroxy-p-benzoquinone, *which is the more formal name of chloranilic acid.)*

Price subject to change without notice.

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BOOKSHELF

Members who wish to be considered for reviewing books are invited to send in their names and subjects in which they are interested. Due to customs and mailing considerations, requests from the United States only can be considered. Copies of these books are not available through ASTM; all inquiries concerning them should be addressed to the publisher.

Timely Aid to Reliability

Quality Control

By N. L. Enrick; The Industrial Press, New York, N. Y. (1961); 216 pp.; Illus.; $5.50.

Reviewed by Frank H. Squires, reliability and and quality control consultant, Los Angeles, Calif.

A NEW EDITION of this excellent introductory text on quality control could not have appeared at a more opportune time. It is primarily concerned with statistical quality control, as distinct from inspection. The purists would say that quality control is, by necessity, statistical quality control. It could not be denied, but in actual practice many plants have been operating with "quality control" departments that were traditional inspection departments, modified by the addition of a little valid sampling in receiving inspection.

Why was it possible to operate with "quality control" departments that were not statistical quality control departments? Because reliability was still an advertising slogan and not a quantitative reality. The tremendous engineering task of designing reliable space hardware has been partially achieved to the extent that production contracts are being let for components and subsystems with high reliability numbers. How will the successful bidders produce components and subsystems with reliability numbers like 0.9992? By making parts that not only conform to the extremely precise engineering tolerance limits, but which also have a high degree of homogeneity. This means that statistical controls will have to be used in every manufacturing process, which is why Mr. Enrick's book is so timely.

The statistical techniques essential to the manufacture of reliable hardware are described in detail. The book abounds in clear and precise definitions. The table of contents is boldly laid out so that the inspector who needs to refresh his knowledge of a particular technique can quickly locate the proper section. For example: "Installing Process Inspection" (Chapter 4), in which the operation of the control chart for averages is clearly demonstrated; "Tolerances and Allowances in Interchangeable Manufacture" (Chapter 7), a minor treatise on a much-debated subject; "Analysis of Variance" (Chapter 18), which takes the occult signs off this useful technique for the benefit of daily practitioners. In emphasizing the value of Mr. Enrick's book for quality control and production personnel confronted by the task of manufacturing hardware with a quantitative reliability requirement, I do not wish to minimize its great value to the many plants manufacturing a vast range of products not yet touched by reliability with a number.

To all those who know, or are willing to be shown, that the maximum yield from repetitive manufacturing operations can only be obtained by statistical analysis and control, this book is as necessary as a stethoscope to a doctor.

On the subject of yield, I was glad to see included a chapter on "Optimising Processing through Evolutionary Operation." Originated by George E. P. Box

(Continued on p. 911)

(*Continued from preceding page*)

of Princeton, this technique for optimising quality, yield, and cost is the essential tool in any cost reduction program. Indeed, a cost control program, however well intentioned, cannot achieve the optimum combination of quality, yield, and cost without statistical analysis and control of the manufacturing processes.

I made several tests of the index by looking for items that a quality control engineer, an inspection supervisor, or an industrial engineer might want information about in the course of his daily work. The index scored every time. There is a tabulation of common interchangeable terms which will also aid the reference seeker.

N. L. Enrick's "Quality Control" will be a valuable aid to the inspectors and producers striving to meet the current demand for high quality and reliability.

Advances in X-Ray Analysis (Vol. 4)

Edited by W. Mueller; Plenum Press, Inc., New York, N. Y., (1961); 568 pp.; $15.

Reviewed by J. V. Smith, editor, X-ray Powder Data File, University of Chicago.

THIS BOOK consists of 38 of the 41 papers presented at the Ninth Annual Conference on Application of X-ray Analysis sponsored by the University of Denver, August 10–12, 1960. The papers are a veritable potpourri: only a really narrow-minded crystallographer could find nothing to interest him here, just as it would take a scientist of very catholic tastes to be inspired by all of the papers. A complete range is covered from the purely academic study of optical transforms to the description of the specifications of commercial X-ray instruments.

Hargreaves gives a nice summary of the use of optical transforms in crystal structure analysis, while Sturcken and Post describe a precision determination of the structure of α-uranium. Eight papers deal with new instruments—a new microfocus generator, a diffractometer furnace, a goniostat, a counter Weissenberg with furnace, a restricted-area fluorescence gadget, new Picker instruments, an automatic fluorescence spectrometer, and a grinder. The article by Henke gives an excellent summary of the processes involving the interaction of 10- to 100-Å radiation with matter; this is certainly an intriguing area of considerable theoretical and practical importance. Another article that should be of interest to many readers is that by Castaing on the fundamentals of electron probe microanalysis. He shows how the element concentration can be calculated from the X-ray emission on the basis of both theoretical and experimental data.

(*Continued on p. 932*)

NEWS OF MEMBERS

Newly elected officers and members of the board of directors of the American Public Works Assn. include **Albert G. Wyler,** director of streets, New Orleans, La., president, and **John A. Lambie,** county engineer, Los Angeles, Calif., and **Roy W. Morse,** city engineer, Seattle, Wash., directors.

During the Annual Meeting of the American Society for Metals in Detroit, Mich., new officers were elected, among whom were the following ASTM members: **Carl E. Swartz,** consulting metallurgist, Hinsdale, Ill., national president; **Joseph G. Jackson,** patent lawyer, William Steell Jackson & Sons, Philadelphia, Pa., national treasurer; **John A. Fellows,** assistant technical director, Mallinckrodt Chemical Works, St. Charles, Mo., national trustee; and **John W. Sweet,** chief metallurgist, Seattle, Wash., trustee. **Claude L. Clark,** metallurgical engineer, special steel developments, The Timken Roller Bearing Co., Steel and Tube Div., received the **Albert Sauveur** Achievement Award, and **Alvin J. Herzig,** president, Climax Molybdenum Co., and vice-president, American Metal Climax, Inc., Detroit, Mich., was presented with the 1961 ASM Medal for the Advancement of Research.

John W. Allen, formerly manager of engineering, nondestructive testing, Instruments Div., The Budd Co., Phoenixville, Pa., is now product development engineer, Ward Leonard Electric Co., Hagerstown, Md.

R. S. Bradley, director of research and engineering, A. P. Green Fire Brick Co., Mexico, Mo., retired recently. For many years Mr. Bradley represented his company's sustaining membership in the Society, and also on Committee D-8 on Bituminous Materials for Roofing, Waterproofing and Related Building or Industrial Uses.

Joseph Breckley, head of rubber laboratory, Titanium Pigment Corp., New York, N. Y., retired September 1, 1961. Mr. Breckley joined ASTM in 1944 and was an active member of Committees D-11 on Rubber and Rubber-like Materials and D-20 on Plastics.

Donald F. Clash, plant engineer, Royal Electric Corp., Pawtucket, R. I., retired November 1, 1961. Mr. Clash had been a member of the Society since 1948.

C. William Cline is now sales engineer, Pitchford Scientific Instruments Corp., Pittsburgh, Pa. He had been head, Nondestructive Testing Section, Physical Metallurgy Div., Alcoa Research Laboratories, New Kensington, Pa.

Paul J. Collins, formerly research assistant, Institute of Hydraulic Research, is now engineer, Harza Engineering Co., Chicago, Ill.

William E. Coykendall, Jr., is vice-president, Alberox Corp., New Bedford, Mass. Previously, he was sales manager, Alite Div., U. S. Stoneware Co., New York, N. Y.

George F. Crable, formerly with Gulf Research and Development Co., Pittsburgh, Pa., is now associate professor and chairman, Department of Physics, Geneva College, Beaver Falls, Pa.

George A. Davidson, vice-president, Standard Oil Co. of California, San Francisco, Calif., retired September 30, 1961. Mr. Davidson was the official representative of his company's sustaining membership in the Society.

Harmer E. Davis, professor of civil engineering and director, Institute of Transportation and Traffic Engineering, University of California, Berkeley, Calif., and chairman of the Highway Research Board, has been named an Honorary Member of the American Public Works Assn.

Howard R. Doswell, vice-president and secretary, The Permold Co., Medina, Ohio, retired October 15, 1961. A member of the Society since 1946, Mr. Doswell participated in the activities of Committees B-3 on Corrosion of Nonferrous Metals and Alloys and B-7 on Light Metals and Alloys.

William L. Fink, scientific coordinator, Alcoa Research Laboratories, Aluminum Company of America, New Kensington, Pa., retired at the end of September. A member of the Society since 1951, Mr. Fink has for many years been active in committee work and will continue his interest in ASTM. He is a member of Committees E-4 on Metallography, E-7 on Nondestructive Testing, Joint Committee on Chemical Analysis by Powder Diffraction Methods, Joint Committee on Definitions of Terms Relating to Heat Treatment of Metals, and the Council of the Division of Materials Sciences. Mr. Fink served on the ASTM Board of Directors from 1958 to 1961 and was given the Society Award of Merit in 1956.

Thomas G. Foulkes, assistant chief metallurgist, Bethlehem Steel Co., Bethlehem, Pa., retired recently. Mr. Foulkes was a member of the Society since 1957.

Michael P. Gaus, prior to becoming assistant program director, Division of

(Continued on p. 914)

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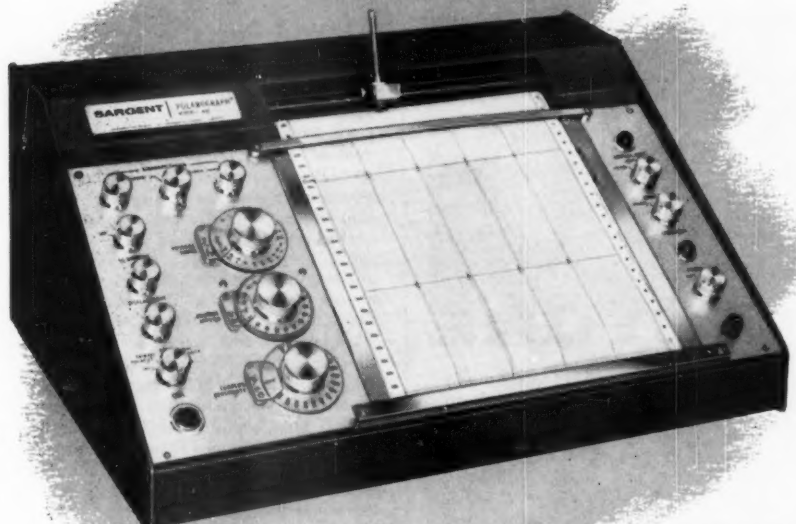

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NEWS OF MEMBERS

(*Continued from p. 912*)

Engineering Sciences, National Science Foundation, Washington, D. C., was assistant professor of engineering mechanics, The Pennsylvania State University, University Park, Pa.

H. M. Hancock, manager, Product Control Dept., The Atlantic Refining Co., Philadelphia, Pa., retired September 30, 1961. A member of the Society for more than 35 years, Mr. Hancock was active in many committees. These include Committee D-1 on Paint, Varnish, Lacquer and Related Products, D-2 on Petroleum Products and Lubricants, D-4 on Road and Paving Materials, D-15 on Engine Antifreezes, D-9 on Electrical Insulating Materials, D-16 on Industrial Aromatic Hydrocarbons and Related Materials, E-1 on Methods of Testing, ASA Sectional Committees A37 on Road and Paving Materials and Z11 on Petroleum Products and Lubricants, and the Philadelphia District Council, of which he was chairman from 1935 to 1938. Mr. Hancock was a member of the Board of Directors of the Society from 1958 to 1961.

James P. Hawke is now chief engineer, J. P. Hawke & Associates, San Francisco, Calif. Formerly he was a consulting engineer in Orinda, Calif.

Cooper F. Hawthorne, vice-president and general manager, Metal Services, Inc., Port Neches, Tex., has been elected second vice-president of the American Hot Dip Galvanizers Assn.

William M. Jennings, Jr., is in the general sales office, Ford Motor Co., Detroit, Mich. He had been sales supervisor, Ex-Cell-O Corp., Lima, Ohio.

Deane B. Judd, assistant chief, Optics and Metrology Div., National Bureau of Standards, Washington, D. C., received the Gold Medal Award of the Illuminating Engineering Society at its Annual National Conference for his contributions in the field of color. In addition to honoring Dr. Judd's personal achievements, his selection as medalist expresses a recognition of the role of color in illuminating engineering.

Roland P. Koehring, section engineer in charge of research at the Delco Moraine Div., General Motors Corp., Dayton, Ohio, was named a Powder Metallurgy Pioneer by the Metal Powder Industries Federation at the 17th Annual Technical Meeting of the Federation, in recognition of the "significance of his pioneering contributions that have advanced the progress of powder metallurgy from a laboratory technique to an industrial technology during the period 1921–1962."

Seymour Livis, formerly technical engineer, Courtaulds Moulded Products, Ltd., Cornwall, Ont., Canada, is research engineer, Transport Div., The Boeing Co., Seattle, Wash.

Jack D. Lubahn is professor of metallurgy, Metallurgy Dept., Colorado School of Mines, Golden, Colo. Previously he was professor of mechanics, Mechanics Dept., University of Wisconsin, Madison, Wis.

Raymond C. Machler retired September 12 as director of research and development, Leeds & Northrup Co., Philadelphia, Pa. Dr. Machler represented his company's sustaining membership in the Society for many years.

James F. Morgan, Jr., is director of engineering and quality control, J. Wiener Co., Muskegon, Mich. He had been with Uhl, Hall & Rich, Niagara Power Project, Niagara Falls, N. Y.

James F. Murphy, formerly senior test engineer, Development and Test Laboratory, ACF Industries, Inc., Albuquerque, N. Mex., is now supervisor of spectrochemistry, Inland Steel Co., East Chicago, Ind.

Roger H. Newton is now a consulting engineer, H. C. Schutt and Associates, Boston, Mass. Formerly he was director, Badger Manufacturing Co., Cambridge, Mass.

John T. Norton, professor in the department of metallurgy, Massachusetts Institute of Technology, Cambridge, Mass., received the Plansee Plaque awarded at the

4th International Plansee Seminar held in Reutte, Tyrol, Austria. Dr. Norton is the first American to receive the plaque, which is given in recognition of fundamental contributions in the field of powder metallurgy.

Austin J. O'Malley, formerly an engineer with Scope, Inc., Woburn, Mass., is now a project engineer with Research and Control Inst., Woburn, Mass.

Robert W. Orr is in charge of engineering on filters, high voltage energy storage and mica capacitors, Aerovox Corp., New Bedford, Mass. He had been engineering manager, Chemical and Dielectrics Div., AMP, Inc., Elizabethtown, Pa.

L. A. Penn retired September 30, 1961, as chief chemist, Tidewater Oil Co., Martinez, Calif. In addition to representing his company's sustaining membership in the Society, Mr. Penn represented his company on Committees D-2 on Petroleum Products and Lubricants and E-19 on Gas Chromatography. He also was a member of the Northern California District Council.

Harry C. Plummer, director of engineering and technology for the Structural Clay Products Inst., Washington, D. C., was made a fellow of the Construction Specifications Inst. at its recent annual convention in New York City. The first non-architect to receive this honor, he has been secretary-treasurer of the institute for the past six years.

Arthur J. Raymo, formerly factory manager, Baldwin-Lima-Hamilton Corp., Philadelphia, Pa., is now factory manager, The Bendix Corp., Kansas City, Mo.

Thomas G. Reynolds, formerly with SunOlin Chemical Co., Philadelphia, Pa., is now with Thatcher & Patient, Inc., Clayton, Mo.

W. E. Santoro has been appointed technical director of James B. Sipe and Co., Pittsburgh, Pa. He had been head, Research Div., The Monroe Sander Corp., Long Island City, N. Y.

Morton Schwartz, previously with The O. Hommel Co., Carnegie, Pa., as a ceramic engineer, is now supervisor of quality control, ATCO Ceramics Corp., Keyport, N. J.

Al Steyermark, head of Microchemical Dept., Hoffmann-LaRoche, Inc., Nutley, N. J., received the Fritz-Pregl-Plaque of the Austrian Microchemical Society for his contributions to the field of quantitative organic and microanalysis, and for his chairmanship of various national and international committees for advancement of this field.

Howard L. Stier has become director of quality control, United Fruit Co., Boston, Mass. He had been director, Division of Statistics, National Canners Assn., Washington, D. C.

Frank Tessitor, formerly engineer, U. S. Bureau of Reclamation, Washington,

(*Continued on p. 916*)

NEWS OF MEMBERS

(*Continued from p. 915*)

D. C., is general engineer, ICA Mutual Security Mission to China, San Francisco, Calif.

R. A. Wilkins, vice-president, Revere Copper and Brass Inc., Rome, N. Y., retired October 1, 1961. Mr. Wilkins has been a personal member of the Society for more than 30 years, and was the representative of his company's sustaining membership. He was a member of Committees B-5 on Copper and Copper Alloys and B-2 on Nonferrous Metals and Alloys for many years, and also served on the Central New York District Council.

Mabel F. Wilson is now a research chemist, Plastics Div., Allied Chemical Co., Morristown, N. J. Formerly she was senior chemist in charge of spectroscopy, Air Reduction Co., Inc., Research Laboratory, Murray Hill, N. J.

Leon Zeldis, director-manager, Industrias Textiles Noveltex S.A.C., Santiago, Chile, has been appointed by Inditecnor, the Official Chilean Standards Inst., to prepare drafts and proposals for standards in the textile field.

DEATHS

Louis Anderson, retired chemical engineer, chief chemist, and director of research, Alpha Portland Cement Co., Easton, Pa. (April 7, 1961). Mr. Anderson, a member of the Society for almost 50 years, was a member of the Board of Directors from 1925 to 1927 and served on Committees C-1 on Cement, of which he was an Honorary Member, C-12 on Mortars for Unit Masonry, and several subcommittees of E-1 on Methods of Testing.

Howard G. Curtis, head, Canals and Pipelines Section, Bureau of Reclamation, Engineering Center, Denver, Colo. (June 11, 1961). Mr. Curtis, who joined the Society in 1960, was a member of Committee C-13 on Concrete Pipe for more than 10 years.

Harry D. Foster, Building Code and Fire Protection Consultant, Walden, N. Y. (September 16, 1961). Dr. Foster's committee activities included C-15 on Manufactured Masonry Units, C-8 on Refractories, E-5 on Fire Tests of Materials and Construction, of which he was chairman, and E-6 on Methods of Testing Building Constructions. He represented ASTM on ASA Sectional Committee on Building Code Requirements for Fire Protection and Fire Resistance.

John R. Freeman, Jr., retired vice-president of metallurgy and research, The American Brass Co., Waterbury, Conn. (September 2, 1961). Mr. Freeman was a 40-year member of the Society and over the years was active in committee work. His work covered a wide

(*Continued on p. 918*)

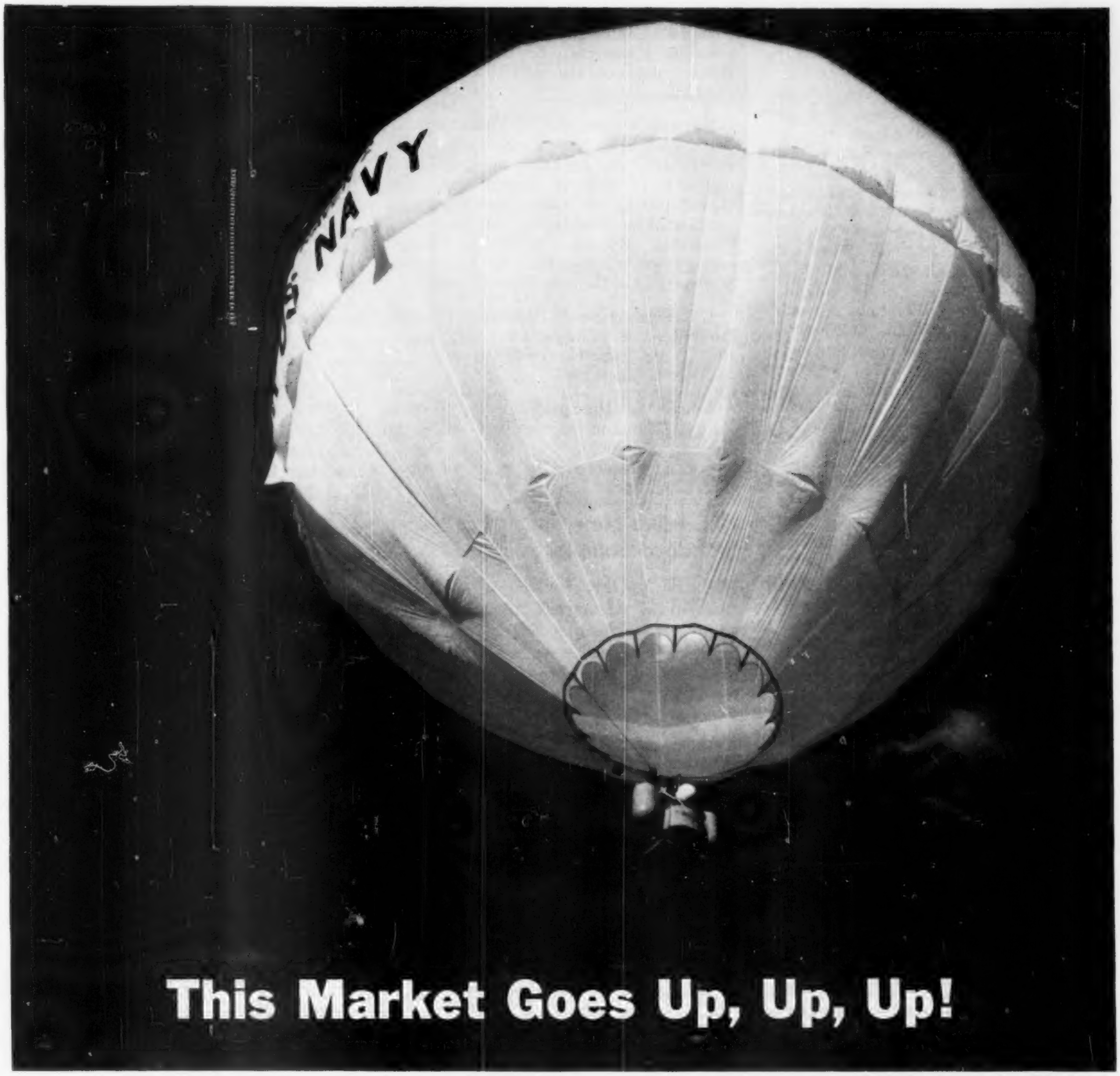

Photo courtesy of Raven Industries and U. S. Navy

LP-Gas is such a versatile fuel that new uses for it arise regularly—such as heating air for the experimental Navy balloon above. It is already high in demand for cooking, heating, air conditioning and scores of other home and commercial uses. Small wonder that among petroleum products, LP-Gas boasts one of the best sales surges—7 per cent last year alone.

Most LP-Gas is produced by wringing out natural gas before it passes into transmission lines. Sinclair Oil & Gas Company owns fully, or in part, 38 gas products plants which process its natural gas output to recover the valuable LP-Gas. It markets the fuel under the Sinclair "Truflame" trademark through distributors in 38 states, and last year rang up a *sales gain double that of the industry.*

As its natural gas output rises, Sinclair is adding gas processing capacity and extending LP-Gas distribution. By expanding its endeavors in growing markets, *Sinclair concentrates on more sales of the most profitable products.*

ASTM—Sinclair salutes the American Society for Testing and Materials. Founded in 1898, ASTM promotes research to develop specifications and test methods which aid all industries in maintaining product quality. The scientific work of its 10,000 members is multiplied many-fold to benefit all consumers. Its D-2 committee, which deals with petroleum products, recently completed specifications for LP-Gas which recognize this fuel's expanding uses.

Sinclair

SINCLAIR OIL CORPORATION • 600 FIFTH AVENUE • NEW YORK 20, N. Y.

FOR FURTHER INFORMATION CIRCLE 1325 ON READER SERVICE CARD

DEATHS

(*Continued from p. 916*)

area and included Committees A-5 on Corrosion of Iron and Steel, B-2 on Nonferrous Metals and Alloys, B-3 on Corrosion of Nonferrous Metals and Alloys, B-4 on Metallic Materials for Thermostats and for Electrical Resistance, Heating, and Contacts, B-5 on Copper and Copper Alloys, B-6 on Die-Cast Metals and Alloys, B-1 on Wires for Electrical Conductors, D-14 on Adhesives, E-4 on Metallography, E-9 on Fatigue, E-7 on Nondestructive Testing, subcommittees of E-1 on Methods of Testing, and several joint committees and administrative committees. Mr. Freeman served on the ASTM Board of Directors from 1945 to 1948.

John W. McBurney, retired senior technologist, National Bureau of Standards, Washington, D. C. (October 5, 1961). During his 40 years of membership in the Society, Mr. McBurney had been active in Committees C-3 on Chemical Resistant Mortars, C-12 on Mortars for Unit Masonry, which he served as chairman from 1937 to 1944 and which elected him to Honorary Membership in the committee, C-15 on Manufactured Masonry Units, E-5 on Fire Tests of Materials and Construction, E-6 on Methods of Testing Building Constructions, E-8 on Nomenclature and Definitions, and ASA Sectional Committee A42 on Specifications for Plastering. In 1956 Mr. McBurney received the ASTM Award of Merit.

Daniel L. Ogden, retired, The American Metal Co., Ltd., New York, N. Y. (July 29, 1961). Mr. Ogden represented his company in Society membership and on committees for many years. In recognition of his outstanding contributions, Committee B-2 on Nonferrous Metals and Alloys elected him to Honorary Membership in the committee in 1956.

J. L. Sigal, chemist, Pittsburgh Testing Laboratory, Pittsburgh, Pa. (August 31, 1961). Mr. Sigal had been a member of the Society since 1945.

Russell L. Thompson, vice-president, James Thompson & Sons, Ames, Iowa (January 25, 1961). Mr. Thompson had been a member of the Society for only a short time.

NBS Issues New Spectroscopic Standard Samples

Two NEW types of spectrochemical standards—a set of eight white cast irons and a set of three naval brasses—have been developed and made available by the National Bureau of Standards. These standards are suitable for both optical emission and X-ray analysis.

Although comprising a graded series in composition for 20 elements, the white cast-iron standards will be certified initially for only ten constituents: carbon, phosphorus, sulfur, silicon, manganese, nickel, copper, chromium, molybdenum, and vanadium. These samples are distributed in the chill-cast form only.

The three naval brass standards, prepared by a special casting technique, are available in both chill-cast and wrought forms. The chill-cast samples are $1\frac{1}{4}$-in. square and $\frac{3}{4}$ in. thick, and the wrought samples are $1\frac{1}{4}$ in. in diameter and $\frac{3}{4}$ in. thick. Both types are equally suitable for use in optical emission and X-ray spectrochemical analysis. Caution is recommended in the use of the chill-cast samples, which are designed for calibration in the analysis of specimens prepared in the same manner. Their use with specimens prepared by other casting techniques may result in considerable bias.

These standards may be purchased for $25.00 per sample from the Standard Samples Clerk, National Bureau of Standards, Washington 25, D. C.

Papers Invited for Spectroscopy Conference

PAPERS ARE being invited for the International Conference on Spectroscopy, to be held June 18–22, 1962, at the University of Maryland, College Park, Md. Papers should emphasize new methods, unconventional experiments, trends in applications of spectroscopy. The program will not include descriptions of analytical methods based on well-known practices and techniques.

Further information can be obtained from Bourdon F. Scribner, National Bureau of Standards, Washington 25, D. C.

U. S. Papers Submitted for Sixth World Power Conference

THE U. S. NATIONAL Committee has submitted a list of 20 papers for presentation at the Sixth World Power Conference, to be held in Melbourne, Australia, Oct. 20–26, 1962. Theme of the meeting will be "The Changing Pattern of Power." The papers will emphasize the changes that have taken place in power production, transportation, and use since the Fifth Conference, in 1956, and will forecast future developments.

The Secretariat for the U. S. National Committee is furnished through the Engineers Joint Council, 345 East 47th St., New York 17, N. Y.

MATERIALS AND TESTING TOPICS

This information is based on literature and statements from apparatus manufacturers and laboratory supply houses. The Society is not responsible for statements advanced in this publication.

FOR THE LABORATORY

Transducer—The Alinco Model 344 is an accurate and reliable universal force transducer incorporating the latest and most effective materials for temperature compensation, low hysteresis, and minimum linearity error. Designed for tension and compression service, the Model 344 guarantees an accuracy of ±0.10 per cent and is available in ranges from 50 to 1,000,000 lb.
Allegany Instrument Co. 3941

Pressure Unit—A new, self-barricaded high-pressure laboratory unit is now available for a wide variety of research operations involving pressures to 5000 psi and temperatures to 650 F. In addition to self-barricading, the unit is easily movable, thus providing maximum flexibility in location. It is compact and fully equipped to include pressure vessels, valving, tubing, and instrumentation and is shipped ready for connection to existing utilities.
Autoclave Engineers, Inc. 3942

pH Analyzer—The new Model J industrial pH analyzer system includes new electrodes and new electrode mounting chambers. The Model J employs an a-c stabilized amplifier which provides stability of 0.01 pH per 24 hr over −20 to +122 F ambient temperature range. Output accuracy and meter sensitivity is ±0.02 pH for the full 0 to 14 pH range.
Beckman Scientific and Process Instruments Div. 3943

Heat-Free Light—The 25-w Burton zirconium concentrated-arc lamp emits a heat-free beam of 15,000 foot candles per sq in. Its powerful Sylvania light source lends itself to such special applications as microscope illumination or projection, photomicrography, metallographs, lens testing, striation detection, optical comparators, transparency projection, spectrophotometers, contact printing, and copying
Burton Manufacturing Co. 3944

Recrystallizer—A new recrystallizer automatically purifies small quantities (about 1 g) of organic compounds in the laboratory with a minimum of attention by laboratory personnel. It is designed to be particularly useful where very pure materials are required for analysis, comparison, or inspection in analytical or industrial quality control laboratories.
Central Scientific Co. 3945

Moisture Analyzer—A new solids moisture analyzer, Type 26-320, uses the Keidel electrolytic cell principle, a proved method of determination of ppm of moisture, to accurately measure moisture in solid samples.
Consolidated Electrodynamics Corp. 3946

Low-Temperature Cabinet—A new line of low-temperature utility cabinets can be used for testing and processing. Called the "Deltair Temp!o," the cabinets are available in 5 and 13 cu ft capacities with 5 temperature ranges to −120 F.
Deltair Products 3947

Laboratory Separator—A new laboratory and pilot-scale separator that permits duplication of production conditions in a compact, counter-top unit has a capacity of 15 to 30 gal per hr, depending on the product being separated. The separator develops a force of 9500 *g* with a bowl speed of 12,800 rpm. The separator is powered by a $\frac{1}{10}$-hp motor that draws only 80 w and operates on 110 v, ac/dc. The motor has specially-greased ball bearings to provide at least 1200 hr use before requiring lubrication.
The De Laval Separator Co. 3948

(*Continued on p. 922*)

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Electronic Micrometer—Operator discrimination is eliminated with the new Model HDR Carson-Dice electronic micrometer. Measurements are displayed on a four-digit counter reading to 20 millionths of an inch. There is a convenient external zero reset for the counter which may be easily zeroed in at any point within the work capacity of the instrument, permitting rapid shifting of fixtures and set-ups.
J. W. Dice Co. **3949**

Multitester—A new 5-mg to 50-ton range multitester called a Drage unit performs tension, pressure, and bending tests on a variety of substances. The linear deformation speed of the unit is independent of the resulting load and may be varied from 1 to 1000 mm per min. Its exchangeable load heads are frictionless and without hysteresis and can be changed during a test. Deformation loads are directly shown on 10 by 10 recording paper. Deformation time is recorded as a second curve. A third curve, or Z axis, can be added to record temperature or thickness change conditions. For routine work, deformation is indicated by a change of distance between sample clamps with ratios of 5:1, 1:1, or 1:5; additional equipment extends the ratios from 10:1 to 1000:1.
J. W. Fecker **3950**

Infrared Analyzer—The Gelman infrared carbon monoxide analyzer incorporates many new design features which increase accuracy and reliability. It has many industrial and laboratory applications where intermittent or continuous carbon monoxide determinations must be made.
Gelman Instrument Co. **3951**

Vacuum Gages—A new line of compact vacuum gages featuring entirely new construction throughout and self-contained miniaturized circuitry is attached directly to the rear of the indicating meter. The complete gage mounts in any panel requiring only a standard meter cut-out.
Hastings-Raydist, Inc. **3952**

Oscilloscope—A new sampling oscilloscope, Model 185B, gives calibrated, high-resolution measurement of nanosecond pulse phenomena. Features conventional controls, direct reading and bright-trace observation, and a standard 5-in. monoaccelerator cathode ray tube.
Hewlett-Packard Co. **3953**

Amplifier—The new Keithley Model 103 is an a-c preamplifier intended to give the best possible signal-to-noise ratios to oscilloscopes and recorders. It has a noise level of less than 0.8 μv rms between 10 cps and 10 kc. The 103 lowers the microvolt measurement threshold over a band-width of 0.1 cps to 100 kc. Applications include measurement of piezoelectric crystal outputs, a-c Hall effect studies, a-c bridge null indicators, and investigations of low-frequency noise in semiconductors.
Keithley Instruments, Inc. **3954**

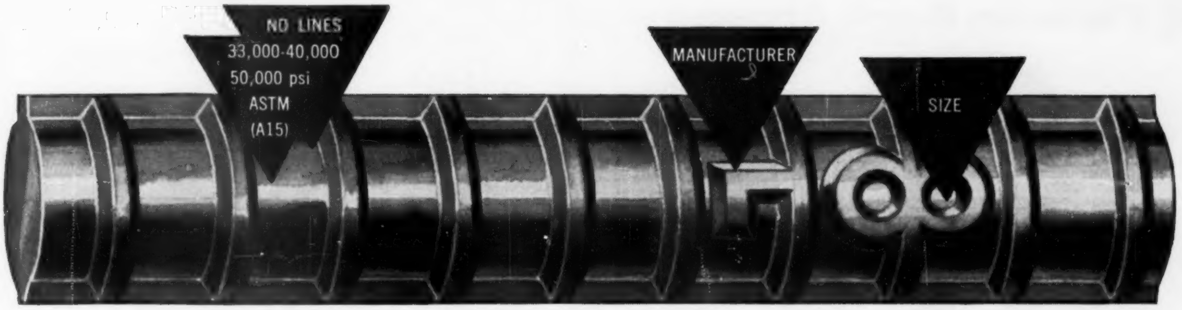
Pulsed X-Ray—The performance of totally enclosed moving parts undergoing vibration and shock tests can now be recorded by a new pulsed X-ray system. Information on hidden part performance during environmental tests gathered through pulsed X-ray testing can be used as the basis for design changes to improve product performance.
MB Electronics **3955**

Visicorder—A 24-channel, direct-recording oscillograph has been introduced that can be rack-mounted in industrial, scientific, and aerospace instrumentation systems or supplied in a specially designed case for table or bench use. The new instrument is called the Model 1508 Visicorder. It fits 24 direct-recording channels into only 7 in. of rack height.
Minneapolis-Honeywell Regulator Co. **3956**

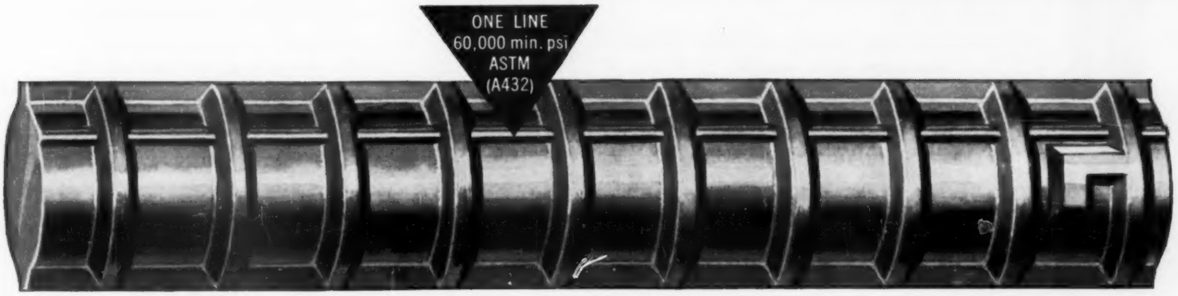
Recording System—A further advance in analog recording and reproduction systems for general industrial and research applications is announced with the development of a model providing $10\frac{1}{2}$-in. tape reel capacity. Designated Model M204, the new system achieves 0.2 per cent precision.
Mnemotron Corp. **3957**

Proving Rings—A new line of proving rings accurate to $\frac{1}{20}$ per cent of applied load, called the Series 200, were developed to meet the increasing accuracy demands in calibrations of rocket thrust stands,

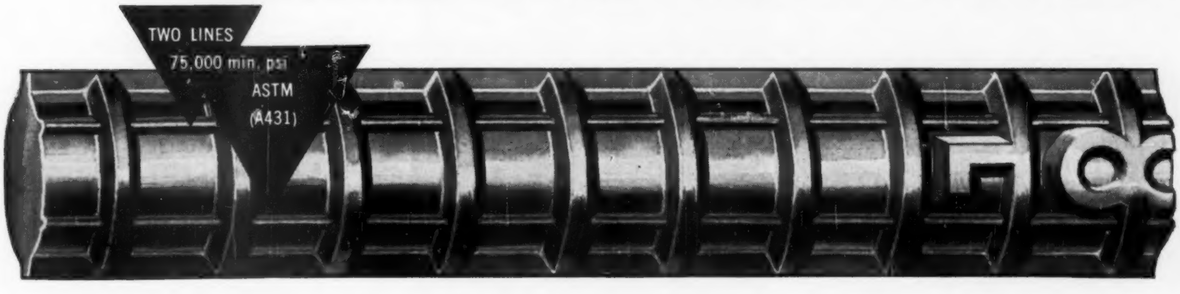
(*Continued on p. 925*)



ROLLED-IN MARKINGS



SHOW SIZE AND STRENGTH



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fast, easy identification saves construction time and cost

Metallurgical research has developed high-strength steels that substantially improve the efficiency and economy of reinforced concrete design — saving as much as 15% of the total construction cost of the structure.

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FOR THE LABORATORY

(*Continued from p. 922*)

physical testing machines, and weighing systems. The capacity of the rings has also been extended in this new line, ranging up to 1,200,000 lb in compression-type rings.
Morehouse Machine Co. **3958**

Gamma Analyzer—The gamma analyzer, Model GSS-1B, operates automatically without adjustment to scan, record, and analyze emitters having energies varying from 0.003 kev to 3 Mev. The system is designed to provide a complete spectral analysis with better resolution. It is capable of analyzing the gamma spectra from 0.1 kev to 6 Mev.
Nuclear Measurements Corp. **3959**

Oscillograph—A continuous oscillograph recorder conversion for standard oscilloscopes, the Mark II, is a system for simultaneous viewing and direct recording of oscilloscope traces. The instrument, weighing 12 lb, is self-contained and can easily be attached to any conventional oscilloscope. Multi-trace scopes can also be used with it for multi-channel recording.
Par Products Corp. **3960**

Temperature Probe—A new, easy-to-use temperature measuring system, designed primarily for use with granular or powdered materials is highly portable and extremely fast. The system may be used wherever temperatures must be measured in out-of-reach places. Temperatures from 20 to 150 F can be measured with exceptional accuracy. Internal mercury batteries normally last up to 5 yr, maintaining accuracy without calibration adjustment.
Radson Engineering Corp. **3961**

Power-Supply—A noise-free family of power supplies featuring precise voltage regulation for both line and load has been announced. The six Sorensen QIS 60-cycle models and the six DQIS 400-cycle models are transistorized, miniature 115-v ac/dc, sine-wave inverters. Operating from 12- or 28-v dc inputs, outputs, obtained from a Class B amplifier, are 20, 40, or 60 w.
Raytheon Co. **3962**

Pulverisette 2—The Pulverisette 2 will work with a wide range of either wet or dry material. Some applications of the Pulverisette 2 are for grinding alumina, pigments, silicates, metal powders, enamel, glass, quartz, ceramics, cement, rock (up to Mohs hardness of 9), coke, coal. It is especially suited for work with caustica, dust-forming, and poisonous materials. Radioactive substances can be ground to analytical fineness (up to 1 μ).
Schuco Scientific **3963**

Filter Chambers—The capacity of the "full-view" filter chambers for filtering corrosive chemicals is now increased. The Model L-80, constructed of transparent high-temperature lucite, has a filtering capacity of 800 to 1200 gal per hr. It is 28-in. high and 9-in. in diameter and weighs approximately 25 lb.
Sethco Manufacturing Corp. **3964**

Environmental Test Cabinet—Zerolab Model 2-300, new test chamber capable of producing environmental temperatures from −320 to +400 F, permits functional tests for a wide variety of electronic, mechanical, and solid-state components for abilities to withstand extremes of heat, cold, and vibration.
Solar Systems, Inc. **3965**

Ultrasonic Cleaner—The generator Model MS 90 has a power capability of 90 w, 360 w peak. It contains a single tube in a half-wave self-rectifying circuit. Generator works on a scanning principle for more efficient over-all cleaning. Input 117-v ac, 60 cycle. Dimensions: 11 in. wide by 10 in. deep by 6½ in. high.
Sonic Systems, Inc. **3966**

Micro-Checker—A new, precision-built, mechanical means of checking displacement-type transducers, such as LVDT, strain gage, variable reluctance, etc., is called the Model TK-501 micro-checker. Displacement of the transducer can be measured down to 0.000001 in.
Techni-Rite Electronics, Inc. **3967**

Adhesives Tester—The Concora folder-gluer mechanically folds the scores put in by the Concora boxboard scorer, it applies a glue line along one side of the sample,

(*Continued on p. 926*)

FOR THE LABORATORY

(*Continued from p. 925*)

crushes the two folded scores to any desired caliper, and applies pressure to the glue line for any desired length of time. The Concora folder-gluer mechanically folds a scored sample similar to the actual folding in production, giving a much more accurate evaluation of the bending qualities of the board under question. Adhesives can be evaluated for spread characteristics, setting time, and holding powers.
Testing Machines, Inc. **3968**

Oxygen Flask—Explosion-proof cabinet, incorporating novel infrared firing device, provides complete protection during combustion of organic compounds by the Schoniger oxygen flask technique. Specimen, wrapped in black paper, is ignited within the charged, clamp-closed flask by the concentrated intensity of a beam from a 150-w lamp focused by a mirror sealed within the lamp envelope. Push-button lamp switch is on top panel of cabinet.
Arthur H. Thomas Co. **3969**

Oxygen Analyzer—The development and production of a new precision instrument, the DO-100 continuous dissolved-oxygen analyzer, measures and records micro quantities of dissolved oxygen in boiler and other high-purity-water systems. The instrument is electro-chemical and direct-acting in operation.
Wallace & Tiernan, Inc. **3970**

NEW LITERATURE

Corona Testing—An engineering specifications bulletin with complete data on a new line of integrated corona test sets, corona-free high-voltage testers, corona detectors, and corona pickup networks has been prepared.
Associated Research, Inc. **6529**

Stress-Strain Gage—A unique bonded-resistance foil-type stress-strain gage is described in a product *Data Sheet No. 4323*. The data sheet provides information on the use of the stress-strain gage as a simple and automatic computing device which solves stress-strain equations without complex calculations by the user.
Baldwin-Lima-Hamilton Corp. **6530**

Ovens—New illustrative 2-color, 4-page *Bulletin No. 1961* entitled "Blue M Power-O-Matic 60 Saturable Reactor Industrial Batch Ovens" describes mechanical convection horizontal airflow ovens.
Blue M Electric Co. **6531**

Thermometers—New *Catalog 620*, "Thermometers, Hydrometers for the Laboratory" contains specifications and prices of a complete line of hydrometers and thermometers including general use from −200 up to 1050 C, precision use up to 0.01 C accuracy, ground joint, dial, and special-purpose types. The thermometers feature permanent markings, lines, and numbers which will never lose their coloring.
Brooklyn Thermometer Co., Inc. **6532**

Viscometers—*Bulletin No. 20* offers a complete line of all sizes and kinds of viscometers for use in laboratories in the petroleum, chemical, aviation, missile, atomic, and pharmaceutical industries. Included are all ASTM types.
Cannon Instrument Co. **6533**

Vacuum Pumps—High vacuum pumps and components are the subjects of a new 6-page, illustrated *Brochure No. 2*. Described in detail is the Cenco series of two-stage Hyvac vacuum pumps ranging in capacity from 21 to 140 liters per min. The pumps in this series work on a concentric rotor-rotating vane principle which significantly reduces noise and vibration. Hyvac pumps have a vacuum guaranteed to better than 0.0001 mm Hg.
Central Scientific Co. **6534**

Catalog—A 16-page *Catalog No. 60* describes test equipment for paper, metal, adhesives, plastics, rubber, cement, and textiles.
Custom Scientific Instruments, Inc. **6535**

Chlorine Analyzer—A new folder-type *Catalog 17B2200* describes the F&P Anachlor residual chlorine analyzer, a continuous amperometric analyzer for water supplies and sewage effluents.
Fischer & Porter Co. **6536**

(*Continued on p. 927*)

NEW LITERATURE

(Continued from p. 926)

Tensile Testers—Laboratory accuracy and production-inspection swiftness are combined in the two tension testers described in *Bulletin 750/P*. The brochure gives complete specifications for the Hunter Model "TT" tester, which is specially designed for testing the breaking strength of electrical leads, terminals, and connectors, and its versatile companion Model "TJ" tester which is equipped with two automatic jaw pairs for tension testing many small parts or material samples as well as electrical leads and connections.
Hunter Spring Co. 6537

Feedwater—*Bulletin 30*, a new 24-page booklet titled "An Introduction to Boiler Feedwater Treatment" answers some questions like: "How Pure Must Feedwater Be?" "How Does Operating Pressure Influence Boiler Water Composition Requirements?" and "What is Meant by 'External' and 'Internal' Feedwater Treatment?"
Nalco Chemical Co. 6538

Density and Moisture Testing—A new publication, the d/M-Gauge *Newsletter*, reports on applications of the d/M-gauge system of nuclear instruments, which are used in measuring moisture and density. The newsletter provides d/M-gauge users with an opportunity to express their viewpoints, ask questions, and thereby promote an exchange of ideas. Users are invited to report their applications in the newsletter. Copies of the d/M-gauge *Newsletter* are available without charge.
Nuclear-Chicago Corp. 6539

Calorimeter Controller—An automatic controller for adjusting jacket temperatures in adiabatic bomb calorimeters is announced in a new 4-page *Bulletin 2600*. This thermistor-actuated system adds either hot or cold water to a calorimeter jacket in the variable amounts required to maintain an equal temperature balance. It can be used with either old or new Parr adiabatic calorimeters to save operating time and to achieve excellent repeatability in calorimetric tests.
Parr Instrument Co., Inc. 6540

Electron Probe—A new 6-page folder providing complete data and specifications on the Norelco electron probe microanalyzer explains operating principle of the instrument in direct chemical analysis of samples less than 1 μ in area and 1 μ in depth involving approximately 1 $\mu\mu$g of material.
Philips Electronic Instruments 6541

Catalog—New issue of *Lab-Oratory, Vol. 63* describes ovens, incubators, centrifuges, vacuum centrifuges, new pipetors, a Hi-accuracy bath with 0.005 C uniformity, and a magnetic agitated bath with only one moving part.
Schaar and Co. 6542

Glassware—Newly issued 4-page folder on Servofrax arsenic trisulfide glass is offered. A nontoxic, noncorrosive, homogeneous glass, Servofrax is widely used in sophisticated infrared instrumentation

(Continued on p. 929)

NEW LITERATURE

(*Continued from p. 927*)

where stability and increased transmission are vital. The folder describes the optical, chemical, physical, and thermal properties of the glass, as well as the special reflection-reducing coatings that are available.

Servo Corporation of America **6543**

Electric Vibrators—A new 12-page *Bulletin 81461* on electric vibrators has complete data and specifications on 14 standard "pulsating-magnet" models, as well as three pneumatic and hydraulic units.

Syntron Co. **6544**

Precision Gages—A complete catalog features an entirely new line of transistorized, precision, low-cost gaging instruments. Included are the Minicom amplifiers, Minicom height gage, bench comparator, Dice thickness gage, and minigage head.

Techni-Rite Electronics, Inc. **6545**

Furnaces—New 44-page *Catalog No. 61* contains illustrated descriptions and full price information on Thermolyne and Temco line of laboratory and industrial equipment including electric furnaces, hot plates, temperature controllers, pyrometers, magnetic stirring hot plates, and clinical apparatus.

Thermolyne Corp. **6546**

Testing Sieves—The 1962 edition of a 48-page handbook on testing sieves and their uses carries complete specifications on the new U. S. Sieve Series ASTM E 11-61; comparison of U. S., Tyler, and principal foreign Standard Sieve Series; and a list of foreign standards using the fourth root of two systems of sieve openings.

The W. S. Tyler Co. **6547**

LABORATORIES

Clark Equipment Co., Jackson, Mich.—Clark Equipment Co.'s Automotive Div. has opened a new engineering test laboratory which simulates field conditions for testing and evaluating the company's line of mechanical and hydraulic transmissions and torque converters.

MATERIALS

Polymers—A new 8-page *Catalog 10240* contains basic information on nine major grades of polymers. Properties of three new material codes, Grades B, X7, and SF, are presented for the first time. Listed performance advantages of the Marbon ABS (acrylonitrile-butadiene-styrene) thermoplastic resins cover the material's combination of toughness, hardness, rigidity, chemical resistance, electrical properties, weight, color range, dimensional stability, and processability. A large chart provides data on typical mechanical, physical, and thermal properties of the various material grades.

Borg-Warner Corp., Washington, W. Va.

Asbestos-Asphalt Test Strips—A report describing test strips of asbestos-asphalt paving laid by the New York State Department of Public Works is now available to interested highway officials, engineers, and paving contractors. Entitled "Asbestos Admixture in Asphalt Concrete," *Research Report 60-5*, the fully documented and illustrated report was prepared by the Bureau of Physical Research of the N. Y. State Department of Public Works, and has been reprinted by Johns-Manville as a public service. *Research Report 60-5* describes the purposes of highway pavement, methods of design and construction, and the characteristics of asbestos that make it a valuable additive for asphalt mixes. Copies are available upon request.

Johns-Manville Corp., Manville, N. J.

NEW MEMBERS

The following 68 members were elected from September 11 to October 9, 1961, making the total membership 10,785 . . . Welcome to ASTM. Names are arranged alphabetically, company members first then individuals. Your ASTM Year Book shows areas covered by the respective Districts.

Central New York District

Brown, Martin R., Jr., assistant professor of civil engineering, Rensselaer Polytechnic Inst., Troy, N. Y.

Sinisgalli, Anton A., General Electric Co., Radiation Effects Operation, Weaponology Unit, Syracuse, N. Y.

Central Plains District

Holdredge, V. A., city engineer, Municipal Bldg., Junction City, Kans.

Mateos, Manuel, research associate, Iowa State University, Engineering Experimental Station Laboratory, Ames, Iowa.

Poisner, Ben, manager, General Testing Laboratories, Kansas City, Mo.

Chicago District

National Automatic Laundry and Cleaning Council, C. S. Darling, executive director, Chicago, Ill.

Allred, Winston, E., test department manager, Automatic Canteen Company of America, Chicago, Ill.

Barnow, Samuel, chief engineer, Alfred Benesch and Co., Chicago, Ill.

Egloff, William F., vice-president, Asphalt Corporation of America, Danville, Ill.

Falck, Richard F., metallurgical engineer, Warner Electric Brake and Clutch Co., South Beloit, Ill. [A]*

Palatine, Village of, Ralph F. Marotte, building commissioner, Palatine, Ill.

Sylvester, Norman A., president, Cochrane Laboratories, Inc., Milwaukee, Wis.

Wisconsin, State of, Department of Administration, Bureau of Engineering, R. D. Culbertson, director, Madison, Wis.

Cleveland District

Van Huffel Tube Corp., Donald L. Robinson, chief metallurgist, Warren, Ohio.

Ty, Leoncio N., research chemist, Fasson Products, Painesville, Ohio. [A]

Detroit District

Chevrolet-Saginaw Grey Iron Foundry, M. L. Williamson, plant engineer, Saginaw, Mich.

Belfour, Albert J., director, Belfour Engineering Co., Suttons Bay, Mich.

Mississippi Valley District

Epstein, Edward, Jr., assistant director of research, Refractories Div., H. K. Porter Co., Inc., St. Louis, Mo.

New England District

Barbour, John G., manager, Control Laboratory, Kendall Co., Walpole, Mass.

Doll, Frederick E., packaging coordinator, Packaging Frontiers, Inc., Waltham, Mass. [A]

Healy, Bernard E., Sr., architect, Architectural Associates, Inc., Weymouth, Mass.

Hyland, Francis B., product design, Gillette Safety Razor Co., South Boston, Mass.

Lichman, Jacob, general manager, Key Polymer Corp., Lawrence, Mass.

Mills, Ernest E., associate professor of mechanical engineering, Mechanical Engineering Dept., Northeastern University, Boston, Mass.

Moeller, H. W., packaging materials manager, Packaging Frontiers, Inc., Waltham, Mass.

Rosenberg, Robert A., vice-president, Mitron Research and Development Corp., Waltham, Mass.

Sullivan, Philip J., manager of quality control, Gilbert & Barker Manufacturing Co., West Springfield, Mass.

New York District

d'Adolf, Stuart V., assistant editor, *Rubber World*, New York, N. Y.

Lichter, Arthur S., manager-treasurer, Molecu-Wire Corp., Scobeyville, N. J.

Manko, Howard H., senior associate metallurgist, International Business Machines Corp., Poughkeepsie, N. Y.

Matthieson, Harry, vice-president, Arwood Corp., Brooklyn, N. Y.

Oyster Bay, Town of, Office of Town Engineer, Arthur N. Gilbert, deputy town engineer, Oyster Bay, N. Y.

Sauerborn, John P., technical specialist, CRT and DVST Engineering, Allen B. DuMont Laboratories, Division of Fairchild Camera and Instrument Corp., Clifton, N. J.

Schiefer, Carl E., senior associate engineer, Plastics Laboratory, International Business Machines Corp., Poughkeepsie, N. Y.

Skeist, Irving, president, Skeist Laboratories, Inc., Newark, N. J.

Wolf, Murray, technical director, Tri-Wall Containers, Inc., New York, N. Y.

Northern California District

Locke, Ralph S., president, Diamond Springs Lime Co., Diamond Springs, Calif.

Northern Plains District

Precision Associates, Inc., Wells J. Horvereid, president and general manager, Minneapolis, Minn.

Martin, Donald W., plant engineer, Gopher State Silica, Inc., LeSueur, Minn. [A]

Thomas, Thomas M., manager, Laboratory Services, Remington Rand Univac, St. Paul, Minn.

Ohio Valley District

Campbell, James E., assistant division chief, Battelle Memorial Inst., Columbus, Ohio.

Cox Donald E., research engineer, Cambridge Tile Manufacturing Co., Cincinnati, Ohio. [A]

Lunsford, Dallas F., chief metallurgist, Perfect Circle Corp., Hagerstown, Ind.

Philadelphia District

Cohn, Sam Lenard, Colonial Alloys Co., Philadelphia, Pa.

Jaacks, William A., assistant general manager, West Jersey Manufacturing Co., Camden, N. J.

Roach, Thomas A., group leader, Manufacturing Technical Service Dept., I-T-E Circuit Breaker Co., Philadelphia, Pa.

Pittsburgh District

Meuche, C. L., advisory engineer, Materials Dept., Astronuclear Laboratory, Westinghouse Electric Corp., Pittsburgh, Pa.

Rocky Mountain District

Heinke, W. R., manager, design engineering, Fisher Contracting Co., Phoenix, Ariz.

Robertson, Lawrence M., manager of engineering, Public Service Company of Colorado, Denver, Colo.

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* [A] denotes Associate Member.

Yao, James T. P., assistant professor of civil engineering, Department of Civil Engineering, University of New Mexico, Albuquerque, N. Mex. [A]

Southeast District

Broward County Building and Zoning Dept., T. W. McInnes, director, Broward County Courthouse, Fort Lauderdale, Fla.
Germ, John F., engineer, John F. Humphrey Co., Inc., Knoxville, Tenn. [A]

Southern California District

Conner, Ralph N., Ormond, Inc., Santa Fe Springs, Calif.
Gross, Wayne M., test laboratory group engineer, Convair Astronaut Div., General Dynamics Corp., San Diego, Calif.
Paine, Roy E., consulting metallurgist, Whittier, Calif.
Weil, Henry R., staff engineer, Engineering and Research Dept., Microdot, Inc., South Pasadena, Calif.

Southwest District

Banks, W. L., technical director, National Petroleum Refiners Assn., Tulsa, Okla.
Hodgeman, Herbert H., design engineer, Daniel Orifice Fitting Co., Houston, Tex.

Western New York–Ontario District

American-Standard, Controls Div., Rochester Instruments, William D. Huston, chief engineer, Rochester, N. Y.
Nelson, Ardell H., chief engineer, Dorcon, Inc., Warren, Pa. [A]
Wheeler, John S., president, Ontario Building Materials, Ltd., Toronto, Ont., Canada.

Foreign

Winco S.A.I.C.F., Pedro Uhrowczik, management's assistant, Fabrica No. 3, Ciudadela Province, Buenos Aires, Argentina.
Bello, Mario Montoya, civil engineer, Concretos Pre-Mezclados Arequipa, S. A., Arequipa, Peru.
Drapal, Stanislav, mechanical engineer, Candidate of Technical Sciences, State Research Institute of Material and Technology, Prague, Czechoslovakia.
Hode-Keyser, Joseph, materials and research engineer, City of Montreal, Montreal, P. Q., Canada.
Jarman, E., technical adviser, Council of British Manufacturers of Petroleum Equipment, London, England.
Universidad del Cauca, Facultad de Ingenieria Civil, Daniel Casas O., head, Structural Dept., Popayan, Colombia.
Wildy, Ralph Alderman, materials engineer, Electricity Trust of South Australia, Adelaide, South Australia.

MATERIAL QUESTIONS

Nearly every day the mail at ASTM Headquarters includes some questions about materials, specifications, test methods, or related problems. We feel that the answers, many of which are based on information given us by officers of committees in their capacity as committee officers, are of general interest. For the most part inquiries we receive relate to the activities of the Society, either standards, research work, or publications. Often, an inquiry is such that the services of a consultant or independent testing laboratory are obviously required; in this event we do not hesitate to so recommend.

Stack Sampling

We understand that ASTM has published a procedure for sampling effluents from stacks (stack sampling). Would you please tell us what publication this might be, or, if you do not issue such a procedure, would you refer us to other possible sources?

• ASTM does not publish a procedure specifically for stack sampling. A useful publication in this area is *Bulletin WD-50*, "Gas and Dust Measurement," published by Western Precipitation Corp., Los Angeles, Calif. This bulletin not only discusses theory, it also describes equipment required and outlines the actual steps used to sample stacks. Also very helpful are two articles by Hemeon and Haines, "The Magnitude of Errors in Stack Dust Sampling," and "A New Method for Stack Dust Sampling," which appeared in 1954 in Air Repair and which are available from Air Pollution Control Assn., Pittsburgh, Pa.

ASTM does publish a number of standards in the area of atmospheric sampling and analysis, some of which may be of help. These are listed in the 1960 Index to Standards.

BOOKSHELF

(*Continued from p. 911*)

Seven papers deal with the application of X-ray fluorescence analysis to a wide variety of analytical problems in metallurgy and mineralogy. The high speed and range of application of the method is clearly indicated; on the other hand, many pitfalls for the unwary operator are revealed. This reviewer believes that the modern methods of analysis are dangerously deceptive: pressing buttons appears so easy, but serious errors can be glossed over. Study of these papers shows what can and what cannot be achieved in this field. One paper deals with pulse-height analysis in X-ray fluorescence, another on the effect of surface irregularities, while three papers deal with applications of X-ray absorption techniques. Six papers deal with identification of phases in various chemical systems, one on analysis of amorphous materials, one on particle size measurements, and three on problems concerning oriented specimens such as thin films.

Altogether, the articles indicate the revolution achieved in applied X-ray techniques during the last ten years. How much further the developments can go is anyone's guess, but certainly this volume testifies to the current vigor of the field.

OTS REPORTS

These reports, recently made available to the public, can be obtained from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C. Order by number.

Corrosion

The Use of Volatile Corrosion Inhibitors as a Preservative Medium for Long-Term Storage of Ordnance Materiel—Addendum VII, Results After Ten Years of Exposure, *PB 171 516*, $1.25.

Humidity and Temperature Effects on Atmospheric Corrosion Rates—Literature Report, *PB 171 547*, 50 cents.

Soviet Research on Corrosion of Special Alloys, *61-31480*, $2.75.

Studies of the Hydrogen Damage Mechanism in the Corrosion of Zirconium, *ANL-6332*, 50 cents.

Electrical Resistance Studies of Anodic and Corrosion Oxide Films Formed on Zirconium, *ANL-6259*, 75 cents.

Metals

Annual Report for 1960 Metallurgy Division. Argonne National Laboratory, for U. S. Atomic Energy Commission, *ANL-6330*, $3.50.

Annual Summary Research Report in Metallurgy—July, 1959–June, 1960, *IS 193*, $2.25.

Metallurgy of the USSR, 1917–1957, *60-51188*, $10.

Experimentation, Analysis, and Prediction for Environmental Creep, *AD 258 565*, $2.50.

Surface Tension of Refractory Metals, *AD 258 567*, $1.25.

A New Type of Lightweight Cellular Material (Aluminum-base), *PB 161 770*, $1.75

A Study of Embrittlement of High-Strength Steels by the Hydrogen Isotopes, *PB 171 253*, $1.50.

Properties of Heat-Treated Steel Forgings Compiled, *PB 151 102*, $1.75.

A Flux-Free Method for Joining Aluminum to Stainless Steel, *HW-68789*, 50 cents.

Cryogenic Materials Data Handbook, *PB 171 809*, $7.

The Evaluation of the Effects of Very Low Temperatures on the Properties of Aircraft and Missile Metals, *PB 171 016*, $1.75.

CALENDAR

Nov. 26–Dec. 1—**American Society of Mechanical Engineers,** Annual Meeting, Hotel Statler-Hilton, New York, N. Y.

Dec. 3–6—**American Institute of Chemical Engineers, Annual Meeting,** Commodore Hotel, New York, N. Y.

Dec. 12–15—**American Society of Agricultural Engineers,** Winter Meeting, The Palmer House, Chicago, Ill.

Dec. 26–31—**American Association for the Advancement of Science,** Annual National Meeting, Denver Hilton, Brown Palace, Cosmopolitan, and Shirley Savoy Hotels, Denver, Colo.

Dec. 27–30—**American Statistical Assn. and Institute of Mathematical Statistics,** 121st Annual Meeting, Roosevelt Hotel, New York, N. Y.

Jan. 8–12—**Society of Automotive Engineers,** Annual National Automotive Engineering Congress and Exposition, Cobo Hall, Detroit, Mich.

Jan. 9–11—**American Institute of Electrical Engineers, Institute of Radio Engineers, American Society for Quality Control, and Electronic Industries Assn.;** Eighth National Symposium on Reliability and Quality Control; Statler-Hilton Hotel, Washington, D. C.

Jan. 15–18—**National Concrete Masonry Assn.** 42nd Annual Convention, Americana Hotel, Bal Harbour, Fla.

Jan. 22–24—**Institute of the Aerospace Sciences,** 30th Annual Meeting, Hotel Astor, New York, N. Y.

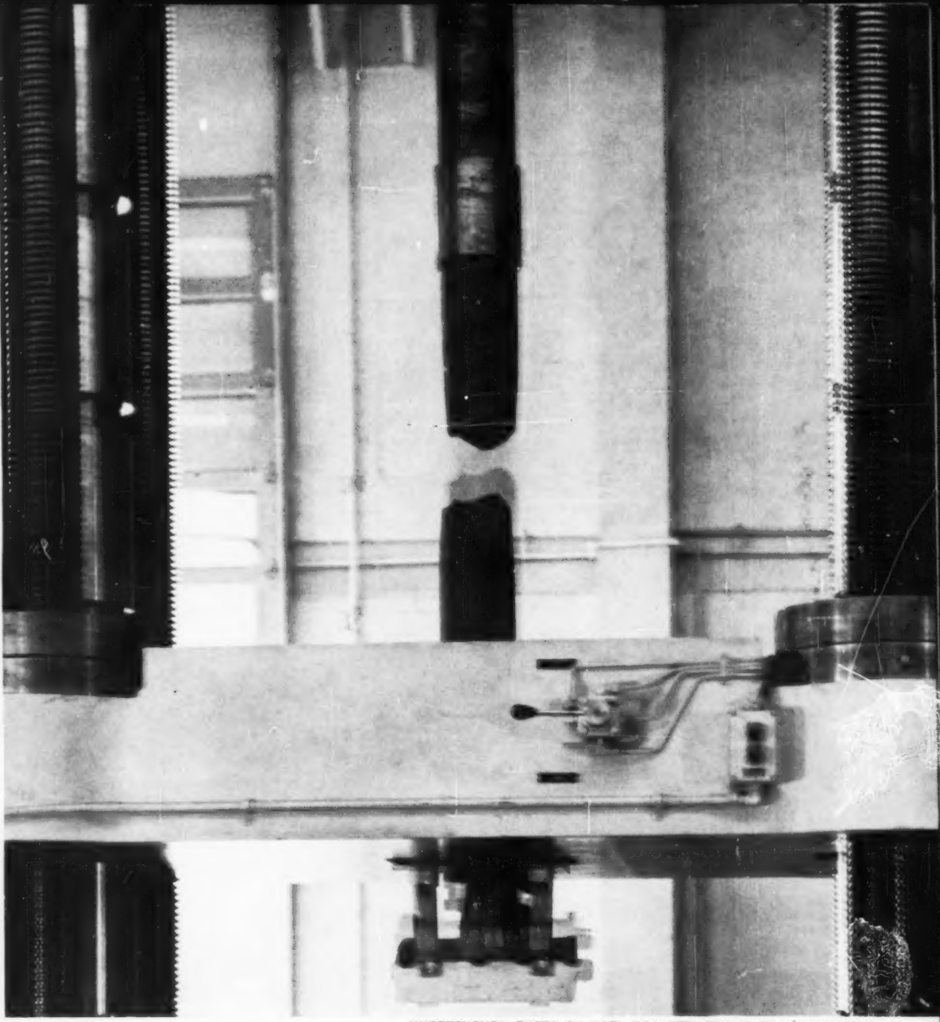
Jan. 25–27—**National Society of Professional Engineers,** Winter Meeting, King Edward Hotel, Jackson, Miss.

Jan. 29–31—**American Society of Heating, Refrigerating and Air-Conditioning Engineers,** Semiannual Meeting, Chase-Park Plaza Hotel, St. Louis, Mo.

Jan. 29–Feb. 2—**American Institute of Electrical Engineers,** Winter General Meeting and Electrical Engineering Exposition, New York Coliseum and Hotel Statler, New York, N. Y.

Jan. 30–Feb. 2—**Society of Plastics Engineers,** 18th Annual Technical Conference, Penn-Sheraton Hotel, Pittsburgh, Pa.

INDEX TO ADVERTISERS



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